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This ESEA Title III report describes fault tree analysis and assesses its applicability to education. Fault tree analysis is an operations research tool which is designed to increase the probability of success in any system by analyzing the most likely modes of failure that could occur. A graphic portrayal, which has the form of a tree, is constructed by a series of logical steps, showing at each stage precisely how a given failure can occur. Mathematical formulas based on the probability of occurrence of individual events are applied to determine the critical path leading to the top undesired event. Among the many advantages of this technique is its usefulness as a device for evaluation of processes as opposed to the more common evaluation of products. The document includes a history of fault tree analysis, principles of fault tree construction, a prototype fault tree with analysis, and evaluation of fault tree analysis as an educational research and planning technique. Although many technical problems are yet to be solved, fault tree analysis holds much promise for application to education. [Not available in hard copy due to marginal liability of original document.] (TT)

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FAULT TREE ANALYSIS:

A Research Tool for Educational Planning

Technical Report No. 1

Including a prototype fault tree applied to the general problem, "Preparation for the world of work"

Developed by

Alameda County School Department PACE Center
225 West Winton Avenue
Hayward, California 94544

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October 1968

ROCK LAFLECHE
Superintendent of Schools of Alameda County
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PREFACE

The development of the prototype fault tree displayed in this report grew out of an extensive assessment of needs in Alameda County related to preparation of youth for the world of work, and the concomitant need for an adequate tool for administrative decisions regarding long-range planning and resource allocation. It is presented here in the hope that it will stimulate creative new approaches to educational problems.

Technical development of the tree and the preparation of this report were done by Belle Ruth Witkin, Research and Evaluation Specialist for the PACE Center, under the general direction of George F. Wilkinson, Center Director.

Special acknowledgment is given to Kent Stephens, Director of Business Services, Seattle Public Schools, who was the principal technical consultant; David Haasl of the Institute of Systems Science; Jon Stephens and Robert Schroeder of the Boeing Company; and Marvin Lamoureux, part-time research assistant for the Center.

Also, special appreciation is extended to the many others who assisted with the construction of the tree by describing possible failure elements and providing critiques for the tree. Their encouragement and help were invaluable and their suggestions are incorporated in the final version of the tree.

Rock La Fleche

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1.0 INTRODUCTION

1.1 Definition

Fault tree analysis is an operations research tool which has been used with signal success as the principal analytical tool of system safety engineering on aerospace projects. The prototype displayed in this document is the first full scale application to an educational problem.

Fault tree analysis is a technique for increasing the probability of success in any system by analyzing the most likely modes of failure that could occur. The fault tree was so named because the completed graphic portrayal of a functional system has utilized a branching process analogous to the development of a tree. The undesired event is located at the apex, and the various contributing events are the branches that extend outward and down.

A fault tree, also called an "event logic network," provides a concise and logical step by step description of the various combinations of possible occurrences within a system which can result in a pre-defined "undesired event." It is a diagram which traces systematically the probable modes of failure leading to the undesired event, the interactions among these modes, and the critical paths.

The process of cause and effect analysis starts with the statement of a critical undesired event which one wants to prevent happening. The fault tree is then constructed by a series of logical steps, showing at each stage precisely how a given failure* event can occur. When the tree is finished, mathematical formulas based on the probability of occurrence of individual events are applied to determine the critical path leading to the top undesired event. On large trees, the data are fed into a computer for simulation and quantification.

1.2 Applicability to education

Fault tree analysis has the following advantages for educational planners: (1) It forces the asking of those questions which identify the things that retard attainment of objectives or, worse, result in absolute failure to reach them. (2) The completed tree makes it possible for expert judgment to be brought to bear on one portion of a problem at a time, and, perhaps most important, shows the interrelationship of all elements in the program in a systematic way providing information to teachers, principals, superintendents or school boards, of a type and in a form which will provide a rational basis for decision-making. (3) Since a good tree has predictive value, it permits redesign of new programs or the building in of safeguards before the program is put into operation. (4) It can also provide continuing evaluation of a program in operation, thus signaling the need for correction to prevent failure. (5) Its greatest value lies in its use as a planning and design technique. When properly implemented, it can assist instructional planners and educational researchers to discover the most probable weaknesses in a plan, and thus provide data for decisions regarding the allocation of resources for the improvement of the system. Most evaluations of new programs are concerned mainly with the "products" of a change. Fault tree analysis also provides for "process" evaluation, and is thus particularly applicable to field studies.

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*By "failure" is meant the inability of a system or portion of a system to perform its expected function(s).

Further advantages are:

a. The analysis is valuable for putting all pieces of a problem together into a systematic whole.

b. It pinpoints areas of responsibility.

c. It enables an administrator, as manager, to analyze value judgments and philosophical statements into manageable, quantifiable statements of events.

1.3 Scope and purpose

This report will cover the following additional sections:

Section 2.0	A brief history of fault tree analysis and a comparison of its use in engineering and the behavioral sciences.
Section 3.0	Principles of fault tree construction.
Section 4.0	A description of a prototype fault tree applied to the general problem, "Improvement of education as preparation for the world of work."
Section 5.0	Analysis of the prototype tree.
Section 6.0	Evaluation of fault tree analysis as an educational research and planning technique.

1.3 Scope and purpose

The tree depicted in this report can to a degree be used as a general model. Restrictions on that use will be noted in Section 5.0. The analysis has been undertaken only to the extent of drawing the tree and verifying the inputs. The quantification of the tree, to determine the most critical paths, will require a probability evaluation of the failure events which is beyond the scope of this document.

The prototype tree displayed here should not be construed as representing the final drawing of the tree. Many other possibilities exist, some of which are discussed in Section 4.4.

The purpose of this report, then, is to give educators some background in fault tree analysis as applied to educational planning and evaluation, together with an example from a problem of pervasive national concern. Future reports will deal with problems of quantification and evaluation of fault trees, simulation, and further application to specific systems.

2.0 HISTORY

The concept of fault tree analysis originally developed as a technique which Bell Telephone Laboratories used to perform a safety evaluation of the Minuteman Launch Control System. Bell engineers discovered that the method used to describe the flow of "correct" logic in data processing equipment could also be used for analyzing the "false" logic resulting from component failures.[1] The format was also well suited to the application of probability theory in order to define numerically the critical fault modes. Haasl points out that the Minuteman Safety Study was successfully completed using the new technique, and provided convincing arguments for the incorporation of a number of equipment and procedure modifications.

Further development of the analytical and mathematical techniques of fault tree analysis has occurred principally in The Boeing Company, and since it was first introduced in 1961, the technique has been applied to many different systems inside and outside the company. Some of these have been a model of the man/machine interface in a manned space system, and analysis of such problems as highway safety and vandalism in the schools.

The application of fault tree analysis to educational problems came about originally through the interest of the Alameda County PACE Center in discovering a predictive tool which would act as a sort of "early warning" signal to educators regarding critical needs to which they should direct their attention. A prime function of PACE[2] Centers in California (funded under Title III of the Elementary and Secondary Education Act, P.L. No. 89-10) has been to develop means of assessing educational needs so that priority could be given to those areas of instruction most in need of innovative or exemplary solutions.

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[1] Haasl, David F. Advanced Concepts in Fault Tree Analysis. Paper presented at System Safety Symposium, June 1965. University of Washington and The Boeing Company.

In 1966, when the Alameda County PACE Center was first funded, many of the really pressing problems were known in a general way. Efforts of most of the California centers therefore centered on identifying in depth and more accurately than before the needs of students, a "need" being defined as "a significant discrepancy between societal expectations and actual performance profiles of a given target population." It should be noted that needs were defined in terms of students, not of the school system itself. Many models were tested by the 21 centers, most of them involving to a greater or lesser degree the perceptions of students, teachers, administrators, parents, or people in the surrounding community.

The results of the Alameda County PACE Center's needs assessment and the relationship of fault tree analysis to the assessing of needs and assigning of priorities are detailed elsewhere.[3] The Center was continuing to search, however, for an analytical tool which would alert administrators, school boards, and parents to emerging aspects of a problem which might be overlooked through the use of conventional research tools. (An analogy might be the development of "multiphasic" health testing in preventive medicine.)

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[2] Acronym for Projects to Advance Creativity in Education.

[3] Master Plan for Occupational Preparation in Alameda County. In preparation.

In the fall of 1966, the research specialist of the Center was put in touch with Kent Stephens, then a member of an aerospace group in The Boeing Company, and first learned about fault tree analysis. Subsequently, Stephens and two colleagues, David Haasl and Jon Stephens, visited the PACE Center to explain the principles of fault tree analysis, and in May 1967 they conducted a week-long training program for school administrators and other interested persons under the sponsorship of the Center and the Alameda County School Department. There the first trees applied to educational problems were drawn, and the possibilities of the technique were explored. Subsequently, Sam Henrie, research director for the Emery Unified School District, and Robert E. Swain, then principal of Emery High School, conducted an analysis based on the district's new communication program, which generated significant information and pointed the way to some needed changes.

The tree displayed in this document was developed out of the experience in that workshop and further technical training received by the writer at a two-week intensive summer institute on System Safety Engineering, conducted by the University of Washington in August 1967.

2.0 HISTORY

The prototype tree (see Appendix) was constructed because one of the most pressing needs of students in Alameda County (as well as elsewhere in California) was found to be better preparation for the world of work. With an unemployment rate of youth 17 to 24 years old running as high as 35 percent in some locations, the problem was an urgent one. The critical undesired event chosen for analysis was "Failure to be employed at an entry-level job with possibilities for advancement." Rationale for the choice of this event is given in Section 4.3.

3.0 PRINCIPLES OF FAULT TREE CONSTRUCTION[4]

In this section are set forth some general principles of fault tree construction. The discussion is limited to the logic network itself, and does not include the mathematical principles.

3.1 Definitions

System: an interacting set of discrete independent elements. A system may include two or more subsystems.

Element or component: the fundamental unit of analysis. May be parts, procedures, ideas, methods--people, materials, equipment, rooms, etc. The element exists in its own right, regardless of the existence of the system.

Interacting: key word. Each element interacts with other elements to produce desirable or undesirable results. If you change the state of one of the elements, you change the system.

e.g. An aircraft with 4 engines.
If one engine goes out, the system is changed.
If two engines go out, the system is further changed.
If both engines out are on the same side, the system is different from one in which one engine on each side is out.

e.g. A sophomore English class with 20 students is a different system from one with 35 students.
A classroom with fixed desks is a different system from one with movable chairs.

3.2 General steps

1. Analyze the system. See Figure 1 for the systems approach.
2. Identify the pertinent subsystems and elements (components).
3. Bound the system for purposes of analysis.
4. Decide whether to use success or failure analysis for problem area identification.
5. For failure analysis, identify major undesired outcomes of the system, and classify according to some index of criticality.

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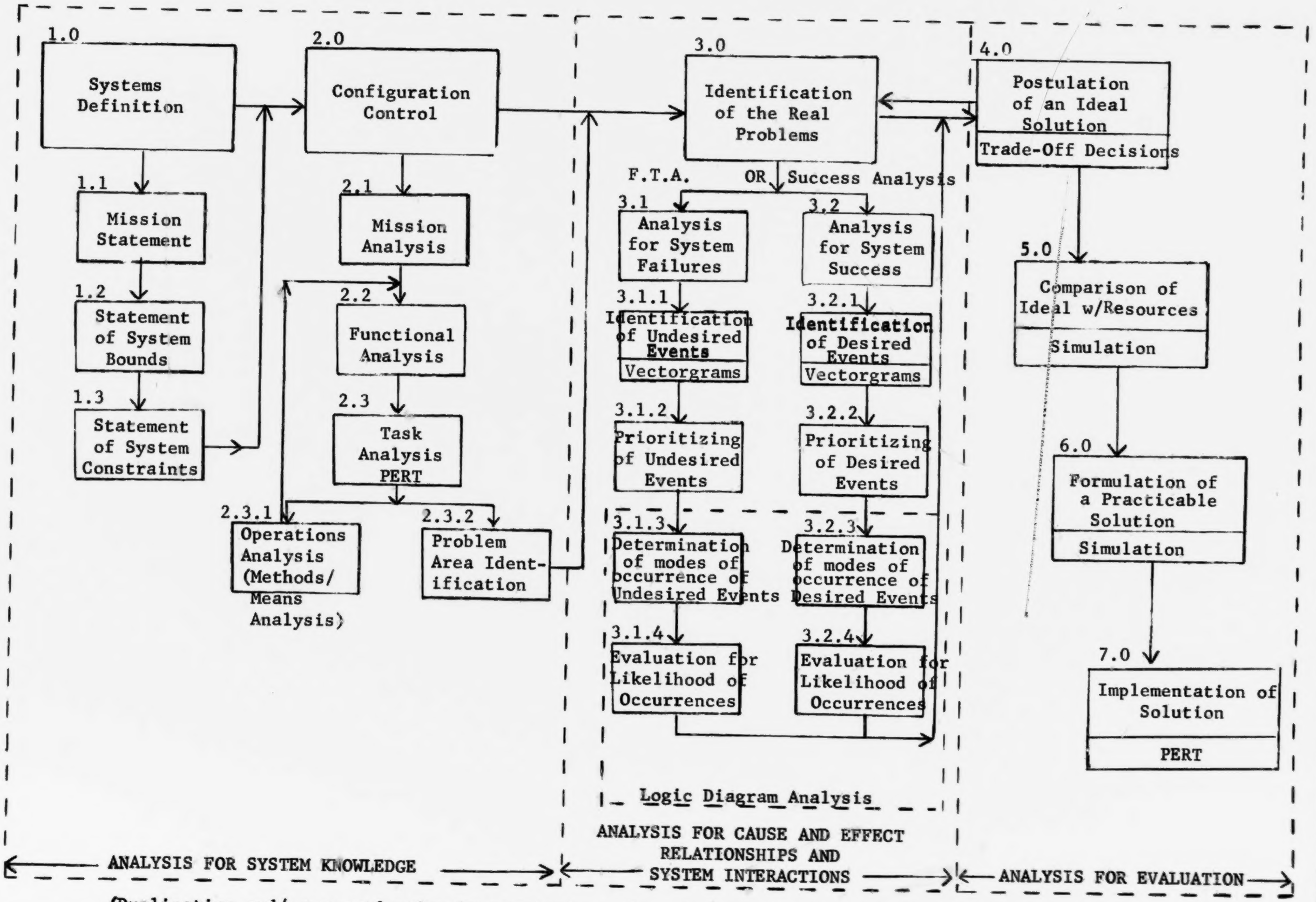
[4] The material in this section is adapted in part from Haasl, op cit, and lectures at the System Safety Engineering institute mentioned in Section 2.0, above.

Figure 1 -- THE SYSTEMS APPROACH


1.0
Systems Definition
1.1
Mission Statement
1.2
Statement of System Bounds
1.3
Statement of System Constraints
2.0
Configuration Control
2.1
Mission Analysis
2.2
Functional Analysis
2.3
Task Analysis PERT
2.3.1
Operations Analysis (Methods/ Means Analysis)
2.3.2
Problem Area Identification
3.0
Identification of the Real Problems
F.T.A.
OR
Success Analysis
3.1
Analysis for System Failures
3.1.1
Identification of Undesired Events
Vectorgrams
3.1.2
Prioritizing of Undesired Events
3.1.3
Determination of modes of occurrence of Undesired Events
3.1.4
Evaluation for Likelihood of Occurrences
3.2
Analysis for System Success
3.2.1
Identification of Desired Events
Vectorgrams
3.2.2
Prioritizing of Desired Events
3.2.3
Determination of modes of occurrence of Desired Events
3.2.4
Evaluation for Likelihood of Occurrences
Logic Diagram Analysis
4.0
Postulation of an Ideal Solution
Trade-Off Decisions
5.0
Comparison of Ideal w/Resources
Simulation
6.0
Formulation of a Practicable Solution
Simulation
7.0
Implementation of Solution
PERT
ANALYSIS FOR SYSTEM KNOWLEDGE
ANALYSIS FOR CAUSE AND EFFECT RELATIONSHIPS AND SYSTEM INTERACTIONS
ANALYSIS FOR EVALUATION

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3.2 General steps

6. Select an undesired event for analysis on the basis of assigned priorities.
7. Determine possible modes of occurrence -- that is, construct the fault tree.
8. Validate the inputs.
9. Evaluate the events for likelihood (probability) of occurrence. Determine critical path(s). (The quantification, computer analysis, and critical path identification are beyond the scope of this report.)
10. Submit to appropriate person(s) (administrator, school board, etc.) for decision.

3.2.1 Analysis of the system

Suppose that it is desired to analyze a new instructional program in English. The system to be analyzed might be the program itself as it operates in one classroom, or in all of the classrooms in a given grade in one school, or in all grades in that school; or in an entire school district, K-12. Once it is decided what the system is which will be analyzed, the system boundaries and elements can be described.

An important consideration in this first step is to specify the type of output expected from the program, preferably in precise behavioral terms. Only if the output, or goal, is clear can decisions be made regarding whether the goal has been met.

For instance, a school wants to improve an in-service training program for teachers. Let us postulate a two-week summer institute designed to prepare teachers to work with students whose first language was Spanish. If the institute has been properly designed, there will be one or more clear statements of exactly what the teachers will be expected to do at the end of the two weeks, and the steps by which they will get there.[5] The undesired event will then be a statement related to the major goal.

3.2.2 Identification of subsystems and elements

These may be arbitrary. For example, if the system is to be a new program in one classroom, then possible subsystems might be the content of the program, teaching facilities, equipment, the students in that classroom, their teacher, the room, time allotted for the program, and teaching strategies.

Elements within a subsystem should be carefully considered, as most of the individual failure events will occur at this level. Even such an item as classroom lighting might be an important element. Elements in the student subsystem might be classified as failures before entering the program, during the program, and following the program. Teacher failure elements might include previous training, previous teaching experience, interest in the new program, preparation for the new program, understanding of the materials, rapport with the students, and so on.

Each subsystem should be designed for success internally, but one task of educators is to insure that putting "safe" subsystems together will produce a "safe" system. It is not automatic. Fault tree analysis shows the interaction effects of these subsystems.

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[5] For a more thorough discussion of behavioral objectives, see Mager, Robert F. Preparing Instructional Objectives. Palo Alto: Fearon Publishers, 1962.
Also, Mager, Robert F. and Kenneth M. Beach, Jr. Developing Vocational Instruction. Palo Alto: Fearon Publishers, 1967.

3.2 General Steps

3.2.3 Bounding the system

For the purposes of analysis, decide on the system bounds, ignoring anything outside. If necessary, however, specify those parts of other systems having important interfaces with the system to be analyzed. For example, since the success of a program might well be influenced by factors outside the classroom, the analyst would determine what other systems interface with the new program--perhaps the home and linguistic invironment of the students, the community, other classes in the school, the students' peers, and so on. Other conceivable systems with which an instructional program might interface are transportation, school recreation program, school administration, the P.T.A., or the secretarial staff. The decision as to the extent to which these interfaces should be analyzed will depend on the judgment of the analyst regarding the influence for failure that other systems might exert.

3.2.4 Problem area identification

It can be seen from Figure 1 that identification of the "real problems" can be accomplished by analysis for either system failures or system success. Theoretically, if one could specify precisely all of the elements in the system which should insure success, including the successful modes of interaction, one would not need failure analysis.

In practice, this is often very difficult to accomplish. Success is much harder to define, and therefore to measure. Success usually covers a range of behaviors. According to one set of criteria, any student might be successful who graduates from high school with a C average or above, if that is the criterion for college entrance. So "successes" might include all students from those just barely making a C average to straight A students. Even delineating some set of minimum standards for success is difficult.

But if success is defined, for example, as ability to enter college, then it is much easier to define failure. Furthermore, ways by which one can fail are often fewer than those by which one can succeed.

Education today is being wracked with controversy over the term, "quality education." It is easy to say what quality education is not, but much more difficult to prescribe what it is. Perhaps it could be said that a quality educational system is one in which the likelihood of occurrence of all identifiable hazardous events, or outcomes, is maintained at an acceptable level.

For example, at a time when the national unemployment rate is around three percent of the labor force, it might be said that no more than three percent of young adults just out of high school and looking for work should remain unemployed. The figures in some locales are running as high as 35 percent, an intolerable situation.

The remaining discussion is predicated on the choice of fault tree analysis for problem identification.

3.2.5 Identification and classification of undesired events

At this stage one "scopes the system" by discovering all identifiable undesired events related to the desired outcomes of the system, and making a tentative drawing of the top of the tree. The analyst need not be an expert on the system being analyzed, but may gather the relevant information from the experts.

In order to assign priorities to the undesired events, a criticality index should be used. The following classification is adapted from system safety engineering:

Example: A potentially explosive classroom

Index of criticality	Critical event
1. Safe - System functioning at "normal" expectancy.	"Normal" classroom interaction.
2. Marginal - Further deterioration of performance will lead to states 3 or 4.	Overt, prolonged student defiance disrupts classroom instruction.
3. Critical - Must take immediate corrective action.	Students leave classroom precipitously during class time without permission.
4. Catastrophic - Intolerable.	Students engage in destructive acts toward property and/or persons.

As another example, consider the performance of an adult on a reading test required for a job. Types of performance might be ordered thus:

1. Safe - Passes test with average score.
2. Marginal - Passes test with minimum score.
3. Critical - Fails to pass test.
4. Catastrophic - Functional illiteracy.

3.2.6 Selection of the undesired event for the top of the tree

The criticality index will assist the analyst to set priorities on those events to be analyzed. The top undesired event should be derived from the clearly stated objectives of the system. What most critical event might occur which, if prevented, would enable the system to function effectively? The assumption is that S = 1 - F, where S is success, and F is the critical failure path. The event or problem should be stated in such a way that it does not suggest or state a solution.

From the system safety engineering standpoint, the events which need analysis the most are the critical or catastrophic ones. For long-range educational planning, marginal events may also need to be analyzed, as they may be the precursors of critical events in the future. Another contrast with hardware systems is that the catastrophic events analyzed usually have a very low probability of occurrence if the system has been well-designed. In the behavioral sciences, however, highly critical or even catastrophic outcomes occur with much higher frequency. For example, typical aerospace safety problems might be (1) to prevent the inadvertent launch of a missile, or (2) to prevent the loss of crew in a manned aerospace vehicle. Contrast the probability of those events with the incidence of fatal highway accidents, rate of unemployment of young adults in urban ghettos, or the probability of violence during demonstrations on a hot summer day.

3.2.7 Construction of the tree

Once the critical undesired event has been stated, the assumptions regarding the system and its subsystems should be clarified. At this point the analyst starts drawing the tree.

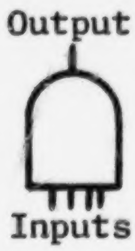
If the analyst does not have a good working knowledge of the system he is to analyze, he can start by reading in the literature, talking to experts, and drawing up a list of failure events which are known to be related to the top event. After scoping the top of the tree, it might be well to work closely on each branch with experts in that area.

The drawing of the tree then consists of asking the question at each step: What are the immediate probable causes of this event? This proximity may be in time, space, or in some other relationship.

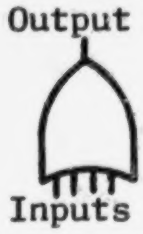
3.2.7.1 Logic operations (gates)

The tree is constructed by showing the relationship between various kinds of events. These relationships are symbolized by "GATES." The following gates are used in this report in the prototype tree. The output from any event leads to the top of a gate, and the inputs lead from the bottom of the gate.

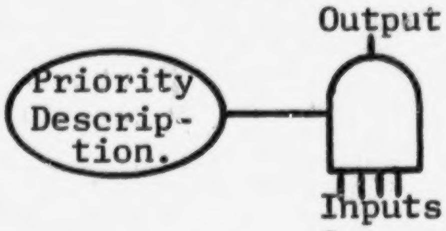
3.2.7.1 Logic operations (gates)


Output
Inputs

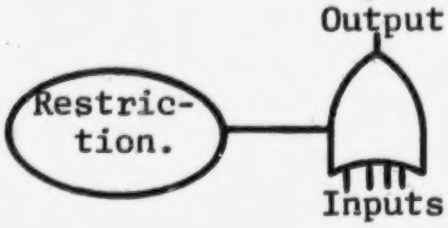
The AND Gate describes the logical operation whereby the coexistence of all input events is required to produce the output event.


Output
Inputs

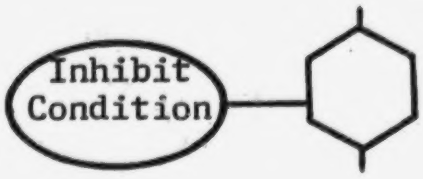
The OR Gate defines the situation whereby the output event will exist if one or more of the input events exists.

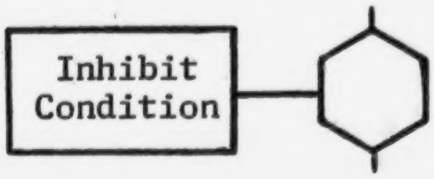

Output
Priority Description.
Inputs

The PRIORITY AND Gate performs the same logic function as the AND Gate with the additional stipulation that sequence as well as coexistence is required.

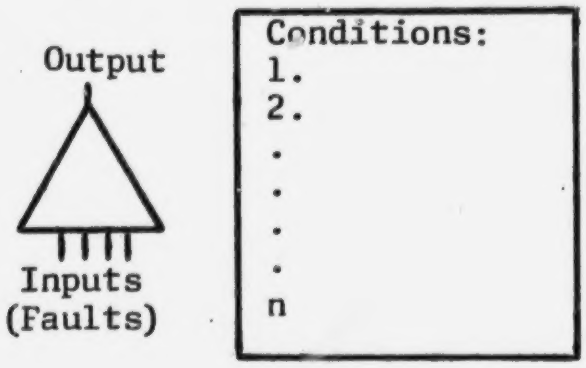

Output
Restriction.
Inputs

The EXCLUSIVE OR Gate functions as an OR Gate with the restriction that specified inputs cannot coexist.


Inhibit Condition


Inhibit Condition

INHIBIT Gates describe a casual relationship between one fault and another. The input event directly produces the output event if the indicated condition is satisfied. The conditional input defines a state of the system that permits the fault sequence to occur, and may be either normal to the system or result from failures. It is represented by an oval if it describes a specific failure mode and a rectangle if it describes a condition that may exist for the life of the system.


Output
Inputs (Faults)
Conditions:
1.
2.
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The MATRIX Gate is an abbreviated representation of a combination of events, which can be represented by a series of AND Gates summed together by an OR Gate. As used in this report, the matrix consists of two or more conditional events, for each of which the same or similar fault events could be the cause.[6]

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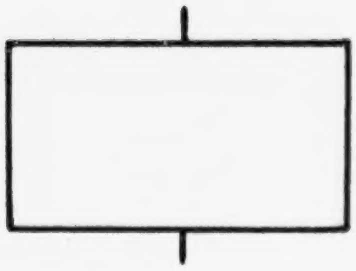
[6] For further discussion, see Ericson, C. A. Advanced Concepts in the Usage of the Matrix Gate. Pamphlet. Boeing Weapon System Safety Division, August 1967.

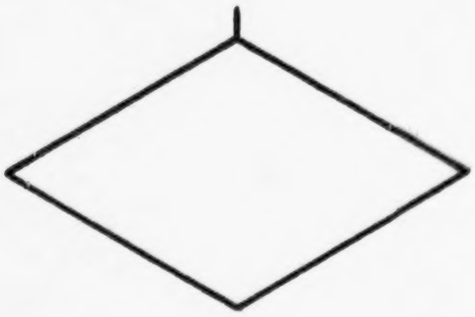
3.2.7 Construction of the tree

3.2.7.2 Types of fault events

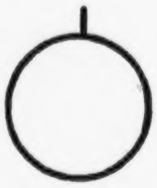
The rectangle identifies an event that results from the combination of fault events through the input logic gate. The event is an input to the logic gate above the rectangle.



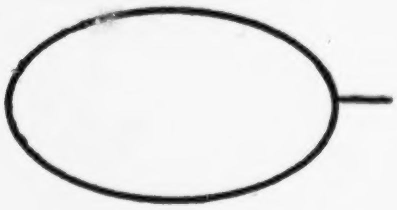
The diamond describes a fault event which is not developed further in the tree, either (1) because the necessary information is unavailable, (2) because the event is relatively unlikely, or (3) because time or other constraints preclude analysis to any further depth.



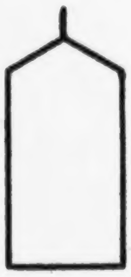
The circle describes a basic fault event that requires no further development. It is a primary failure of a discrete element due to its internal conditions.



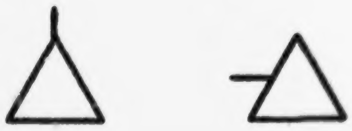
The oval is used to record conditional input to an INHIBIT Gate. It defines the state of the system that permits a fault sequence to occur, and may be either normal to the system or result from failures. It differs from the rectangle in that the oval describes a condition at a particular point in time, while the rectangle describes a condition that is part of the system.



The house indicates an event that is normally expected to occur, such as a phase change in a dynamic system. It is a basic input.



The small triangles are used as transfer symbols. A line from the apex of the triangle indicates a "transfer in" and a line from the side denotes a "transfer out."



3.2.7 Construction of the tree

3.2.7.3 Depth of resolution

Using the foregoing symbols for failure events, conditions, and relationships, a tree of any size desired can be constructed, with the depth of resolution predetermined by time, available knowledge, and detail needed for adequate decision-making. One way to approach this is to decide that each of the events at the top of the tree, just below the critical undesired event, should be analyzed to a level of six or eight or some other desired number. Since the tree starts at the top and rapidly spreads in width and depth, even a relatively small tree with two inputs at each level for each event will reach 32 events by level five. The events in the prototype tree number well over 700, with over 330 end events. The average depth of resolution is seven levels, and some branches extend to level twelve.

3.2.7.4 Determination of logic relationships and types of events

At each new level ask the question, Does this event require the coexistence of two or more other events or conditions? If so, those events are inputs to an AND gate. If any set of events is composed of a number of events any one of which could cause the failure above it, those events become the inputs to an OR gate. There may be many inputs to an OR gate, but each one by itself must be able to cause the failure.

After the logic gates are determined, the next step is to decide which of the inputs are primary, which are secondary, and which are command failure modes. A primary failure, represented by a circle, is a basic failure of some component or element. It is analogous to some failure in an organism. Typical primary failures in the prototype tree are neurological deficits, blindness, deafness, and the like.

A secondary failure, represented either by a rectangle or a diamond, depending on whether the analysis is to go further, is a failure from non-intended environmental conditions. There is an out-of-tolerance condition which brings about the failure event. Most of the events depicted in the prototype tree are secondary failures.

A command mode is one in which the component goes into a "failed" state because someone told it to. It does not represent a failure of the component itself. For example, an employment agency might refuse to place an 18-year old on a job because the employer requested that the minimum age be 21. Command failures can be depicted also either by a rectangle or a diamond.

The above rules are useful mainly as checks for the analyst to be sure that no important events are omitted. They have been taken from system safety engineering. It may well be that further development of fault tree analysis for the behavioral sciences will uncover additional or different principles which are more germane to non-hardware systems.

As the analysis proceeds, it will be found that very similar events or even identical ones will show up in different branches of the tree. For example, stereotypes about mathematics learning might show up in both the student and teacher branches. If the likelihood of the occurrence of these stereotypes is high, they are worth examining in more detail.

The events depicted by circles and triangles will have no further inputs, but appear at the bottom of their branches. As the tree undergoes revisions, the diamonds may be analyzed in more depth, in which case they become rectangles.

When the tree is finished, the gates are numbered to show the levels vertically and the number of gates horizontally. For example, the gate numbered E8 is at the fifth level from the top, and occurs after 7 previous gates at that level in other branches of the tree.

Criteria for a good analysis are validity (is it thorough, comprehensive, and true?) and feasibility (in terms of time, money, and the state of the art). If the analysis generates enough information for decision-making to offset the time and money spent, it is worth doing.

3.2.8 Validating the tree

The rough draft of the fault tree is nothing more than an "argument tree" and should be validated as follows:

a. Each rectangle should state an undesired event.

b. Each and every rectangle should have the following questions asked of it by experts:

    (1) What are the causes of this particular undesired event?

    (2) Are all these causes listed?

3.2.8 Validating the tree

(3) Is each cause listed both necessary and sufficient to cause it to happen? If so, it should go under an OR gate; otherwise it should go under an AND gate.

c. All rectangles which reach terminal points (events which the analyst does not intend to submit to further analysis) should be changed to circles for primary inputs, or diamonds.

d. Redundancies existing on the same level should be sought and combined by redefinition of gates above them where possible.

At various points in time during the construction of the tree, experts should be consulted to verify that the events depicted do in fact exist and that they have the designated relationships. It is often well to call in the experts several times during the drawing of the tree, to check for omissions, interactions, etc.

3.2.9 Determining the critical path(s)

The methods used in aerospace safety engineering to evaluate the likelihood of occurrence of fault events are not applicable to educational systems. The Alameda County PACE Center is now exploring alternate methods of determining probabilities and deriving a critical path.

3.2.10 Submission to decision-maker(s)

If the fault tree analysis shows that changes in the system are necessary:

--- consider what the system would be like with changes (in effect, a new system).

--- go through steps 7 to 9 again.

3.2.10 Submission to decision-maker(s)

--- ask, will the changes *create* other hazards in some way?

N.B. If it is impossible to prevent the *occurrence* of an undesired event, it might still be possible to prevent that occurrence from having an undesired *result*.

3.3 Using the analysis

If the analysis is undertaken during the design of a new program, the decisions based on the tree should lead to design changes or the incorporation of monitoring devices or back-up plans where needed. The completed tree can then provide a verifiable check list of all critical events growing out of the construction of the tree, for use during the program, (1) to allocate responsibility, (2) define communication channels, (3) monitor components for faithfulness to the original plan, and (4) spot potential trouble spots. It can also provide components for PERT.

In a complex ongoing system decisions may be made leading to far-reaching system changes, reallocation of resources, or the development of new programs. A check list derived from the end events of the tree can help an administrator determine whether the system is providing for contingencies, whether further information is needed, and so on.

Although the principal target population is usually determined through assumptions made before the tree construction, the tree can further define who has the problem, to what extent, and at what point in time. The analyst can then indicate areas where surveys or other research would be beneficial to (1) supply missing data, fault events, or probabilities of fault events, or (2) to develop resource allocation strategies.

4.0 A PROTOTYPE FAULT TREE[7]

4.1 Choice of problem

The California State Plan for Title III of the Elementary and Secondary Education Act has classified the major unmet educational needs in the state according to the ten goals of quality education generated by the Pennsylvania study.[8] The goal referring to vocational preparation reads, "Quality education should help every child understand the opportunities open to him for preparing himself for a productive life and should enable him to take full advantage of these opportunities."

In Phase I of the needs assessment undertaken by the Alameda County PACE Center, the area of "better preparation for the world of work" was given highest priority for action. Fault tree analysis was conducted as part of the research directed toward analyzing the problem and finding possible solutions.

Since studies made elsewhere also indicated that one of the most serious problems facing education was that students were leaving high school without salable skills, the question was asked, "How can the education of young people be improved so that they can be better prepared to enter the world of work?" The following analysis was made before constructing the tree:

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[7] See Appendix for the complete fault tree.

[8] A Plan for Evaluating the Quality of Educational Programs in Pennsylvania. Educational Testing Service, Princeton, New Jersey, June 1965.

4.1 Choice of problem

MISSION

To develop a master plan of occupational preparation for youth in the schools of Alameda County.

APPROACH -- Assumptions made:

1) Job entry failure involves preparational deficiencies, including the parameters of basic academic skills, acceptable work habits and attitudes, specialized skills, and career choice.

2) Identification of preparational deficiencies will provide the basis for proper resource allocation aimed at effective occupational preparation.

3) The occupational job seeking population is identified or identifiable.

4) The occupational preparation system must interface with the economic system in order for students to be employed. Therefore failure events outside of the schools must be identified.

5) Occupational preparation is career-oriented. The jobs must show some promise of advancement.

6) Data are available for frequency determination of identified deficiencies.

METHOD

Fault tree analysis for identification of occupational preparation deficiencies.

IDENTIFICATION OF UNDESIRED EVENT

"Failure to be employed full time in an entry-level job with possibilities for advancement."

MODES OF OCCURRENCE

See fault tree in the Appendix.

Although the prototype is constructed in such a way as to serve as a general model, a particular target population was kept in mind as the one for which the stated undesired event would be the most critical under the present social conditions:

4.1 Choice of problem

- The "student" or "applicant" referred to in the tree is actively on the labor market and needs a full-time job.
- He has graduated from high school or has dropped out before graduation. In any event, he has not gone on to junior college.
- He is in the age range 17 to 24. This is the population with the highest unemployment rate in Alameda County, as well as the United States; the available statistics usually bracket these ages.
- In California he is most likely to be black, or Mexican-American.
- He is probably not qualified for a job at higher than entry-level skill.
- The job must provide possibilities for advancement, and therefore not be a cul-de-sac. It need not be in an occupation in which he intends to remain.
- It is assumed that some entry-level jobs demand specialized skills and that some do not.
- Part-time and summer jobs for students still in school or needing less than full-time work are outside the scope of the tree.
- Failures relating to "continuing to be employed" are outside the scope of the tree.

4.2 Analysis of the system, bounds and constraints

The system to be analyzed was defined as "That portion of society's educational system which enables persons to be productively employed for the benefit of society and of the employer."[9] The system was bounded to public schools, grades kindergarten through high school. Subsystems considered are the instructional system (with general, vocational, guidance, remedial, and other components), the administrative system, plant and facilities, and staff.

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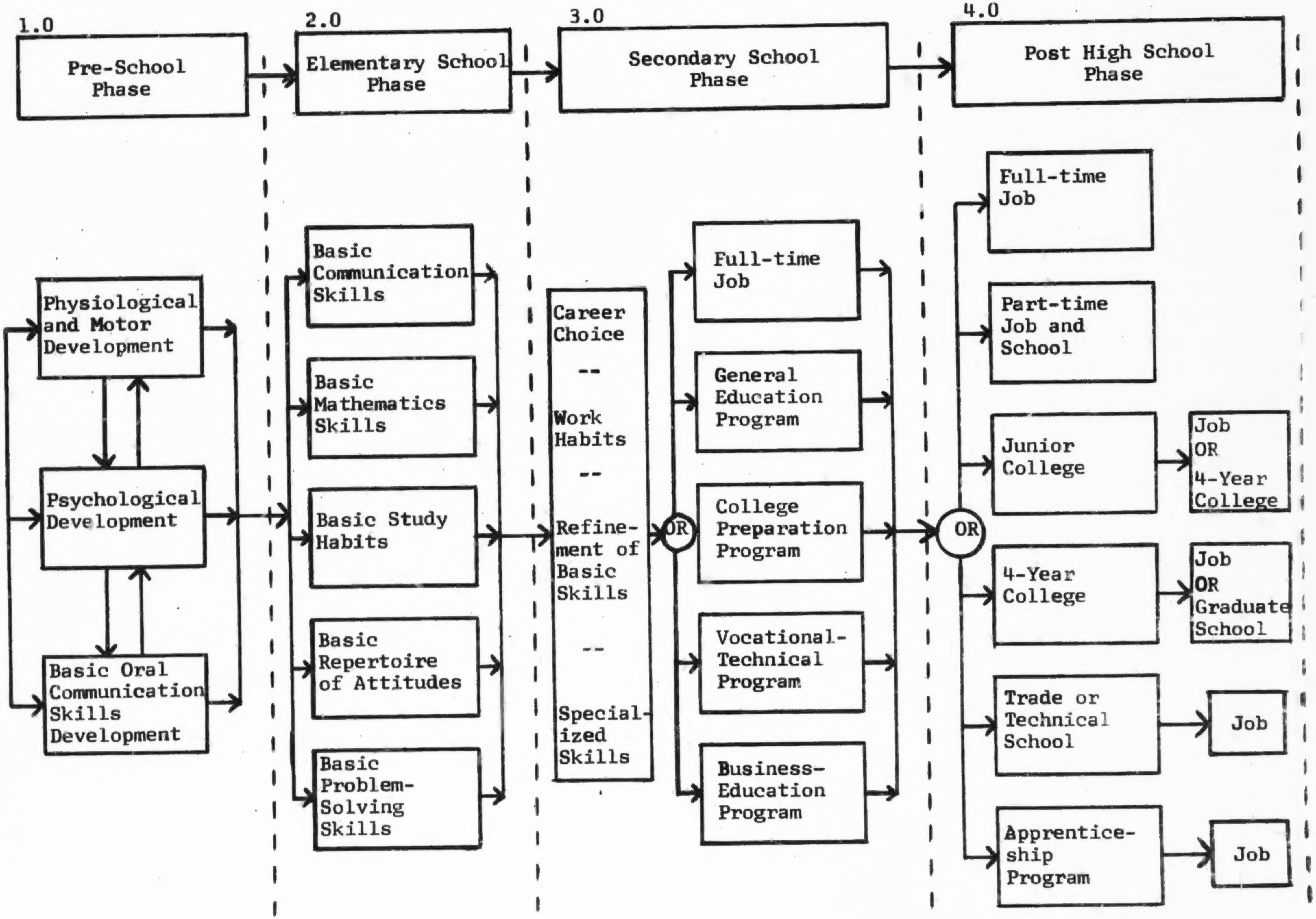
[9] See Figure 2 for a functional flow chart of a hypothetical system.

Figure 2
FUNCTIONAL ANALYSIS OF A HYPOTHETICAL SYSTEM FOR OCCUPATIONAL PREPARATION
Time Phases


1.0
Pre-School Phase
2.0
Elementary School Phase
3.0
Secondary School Phase
4.0
Post High School Phase
Physiological and Motor Development
Psychological Development
Basic Oral Communication Skills Development
Basic Communication Skills
Basic Mathematics Skills
Basic Study Habits
Basic Repertoire of Attitudes
Basic Problem-Solving Skills
Career Choice
--
Work Habits
--
Refinement of Basic Skills
--
Specialized Skills
OR
Full-time Job
General Education Program
College Preparation Program
Vocational-Technical Program
Business-Education Program
OR
Full-time Job
Part-time Job and School
Junior College
4-Year College
Trade or Technical School
Apprenticeship Program
Job OR 4-Year College
Job OR Graduate School
Job
Job

4.2 Analysis of the system, bounds and constraints

Interfaces were made with relevant aspects of other systems -- the home, community, prospective employers, unions, placement agencies, and the economy of the region. Portions of these systems became subsystems of the major system under analysis. There was also the potential for influence on private and technical schools, and junior colleges.

In the hypothetical system used, it is assumed that the "student" on the job market, referred to in the tree, has reached at least the sophomore year in high school. The school does not take a major part in job placement. The system provides little or no systematic prevocational experience, and defers its first vocational courses until grade eleven. It offers possibilities for students to follow college preparatory, vocational-technical, business education, or general programs in high school. Work-study programs may or may not be included. Once a student elects to follow a given program, it is difficult for him to switch and still graduate with his class.

4.3 Selecting the critical undesired event

There are many possible choices for critical undesired events from such a system. Obviously, it is not the sole aim of a comprehensive school system to prepare youth for employment with specialized skills. But in the context of the social and economic problems of our time, it is a disaster of major proportions when up to 35 percent of youth under 25 cannot secure jobs, or jobs that are not dead-end or menial, and that will pay a living wage.

4.3 Selecting the critical undesired event

The event chosen, then, was "Failure to be employed full time in an entry-level job with possibilities for advancement." This was felt to be a long-term problem worth analyzing. An earlier wording of the event used the term, "meaningful employment," but it was discarded as being too ambiguous.

4.4 Scoping the tree

A decision to be made was whether or not to confine the analysis only to those modes of failure having to do with preparation, as events more likely to be within the purview of the school. It was finally decided to extend the analysis to an interfacing with the system of employment itself, thus bringing in factors outside of the control of the student or the schools, but of great importance.

It should be noted that while the analysis was under way, the urgent need to provide temporary jobs for thousands of untrained youth in order to avert another "long hot summer" led many employers to waive their job requirements and to undertake considerable on-the-job training of people heretofore considered unemployable. It is highly improbable that this will be continued to any great extent on a regular basis. Even with such waivers, it has been found difficult to fill thousands of jobs requiring only the most minimum of qualifications. It was interesting to observe, as the drive for jobs in the summer of 1968 accelerated, how first one, then another part of the fault tree came into focus in the news media, validating much of the data in the analysis.

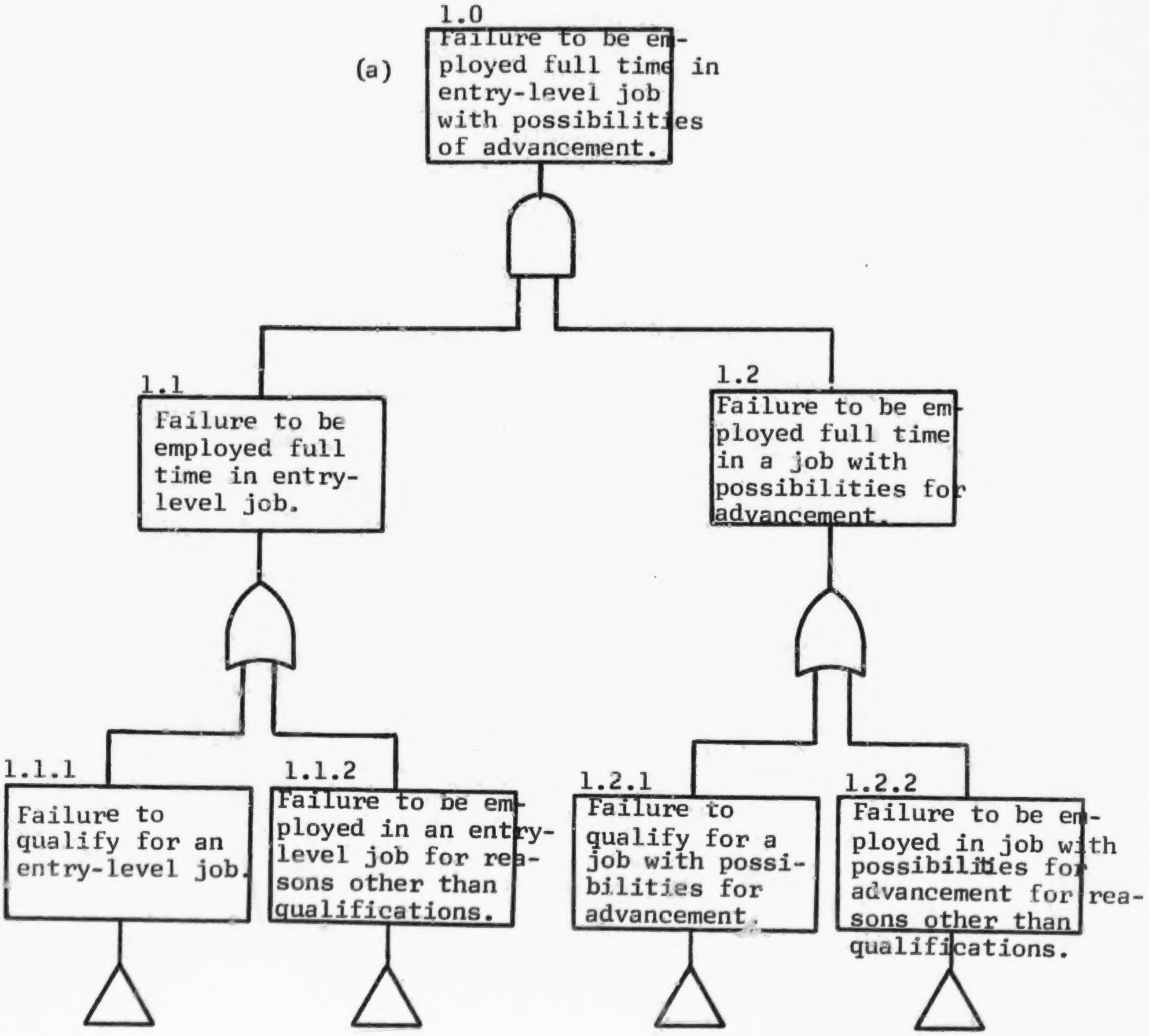
4.4 Scoping the tree

In a rough sense, this is the way the prototype tree was constructed. The question was posed, Supposing a high school graduate walks into a plant for a job interview, what could prevent him from getting that job? In the broadest sense, it could be because he wasn't prepared for the job or because some other factors were operating. In what senses might he be unprepared? He might not have adequate basic skills, specific job skills, or good work habits, etc. What other reasons might prevent him from getting the job? There may be no openings or the employer doesn't like his looks, or his accent, or he couldn't qualify for a driver's license, or the job description calls for males over six feet tall, and so on.

Another assumption made in scoping the tree was that it might be possible to obtain employment without adequate preparation, for the reasons cited above and others as well. If this had not been so, the tree would start with an AND gate. As it is, there is the presumption that either factors related to adequate preparation or factors not related to preparation as such, might cause failure to be employed.

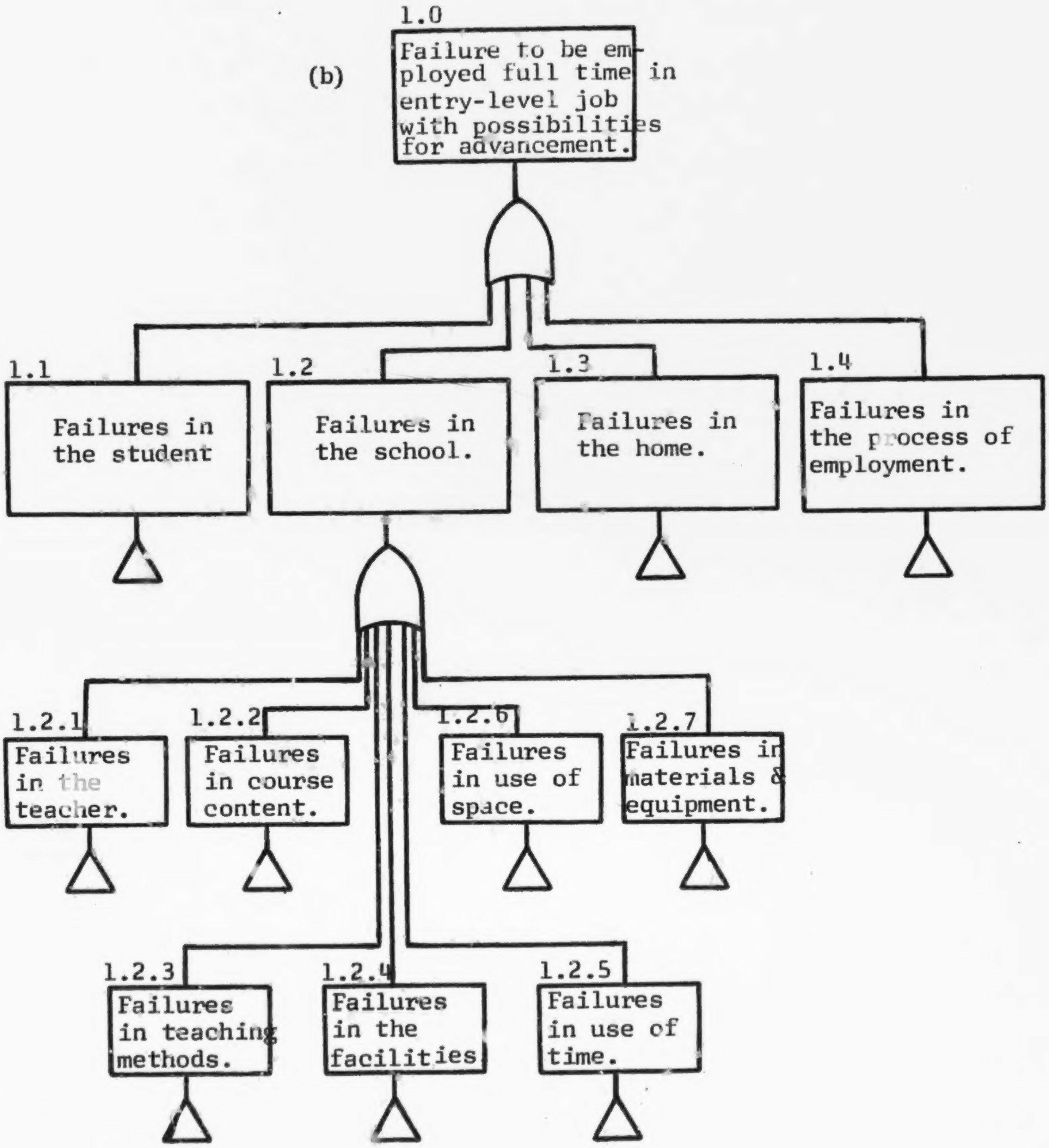
Alternate ways of beginning the tree are shown in illustrations (a) and (b) on pages 30 and 31.

4.4 Scoping the tree


(a)
1.0
Failure to be employed full time in entry-level job with possibilities of advancement.
1.1
Failure to be employed full time in entry-level job.
1.2
Failure to be employed full time in a job with possibilities for advancement.
1.1.1
Failure to qualify for an entry-level job.
1.1.2
Failure to be employed in an entry-level job for reasons other than qualifications.
1.2.1
Failure to qualify for a job with possibilities for advancement.
1.2.2
Failure to be employed in job with possibilities for advancement for reasons other than qualifications.

The tree above should be read thus: The failure in box 1.0 can be caused only by the coexistence of events 1.1 and 1.2. Event 1.1 can be caused either by event 1.1.1 or event 1.1.2. Similarly, event 1.2 can be caused either by event 1.2.1 or by event 1.2.2. Alternate (a) was discarded because it developed that, with a few exceptions, most failure modes related to both sides of the tree. In effect, the two branches were the same, not different, subsystems of the system.

4.4 Scoping the tree


(b)
1.0
Failure to be employed full time in entry-level job with possibilities for advancement.
1.1
Failures in the student
1.2
Failures in the school.
1.3
Failures in the home.
1.4
Failures in the process of employment.
1.2.1
Failures in the teacher.
1.2.2
Failures in course content.
1.2.6
Failures in use of space.
1.2.7
Failures in materials & equipment.
1.2.3
Failures in teaching methods.
1.2.4
Failures in the facilities.
1.2.5
Failures in use of time.

Since both gates are OR gates, any one of the events can cause the top event, and therefore is the same as that event (1.0).

Alternate (b) was discarded because, although it appears to be a neat structuring of the subsystems, as the tree is extended this scoping does not allow for the flexibility and depth of analysis of that of the prototype tree. However, for the analysis of any given instructional procedure or program, the (b) model, especially boxes 1.1 and 1.2, might well be used as a tentative start on the tree.

4.5 Determining the failure modes

The data from which most of the failure events were derived, as well as their relationships, were drawn from a number of sources. A review of the literature disclosed many recent studies done at the University of California at Berkeley, as well as the East Bay Manpower Survey, follow-up studies of graduates of local school districts (the most comprehensive being that done by Oakland Unified School District), and material in professional vocational education and guidance journals. Interviews and meetings were held with district, county, and state vocational education people, school guidance personnel, and people from Youth Opportunity Centers, California State Employment Services, Bureau of Labor Statistics, Kaiser Industries, and university and junior college professors.

The prototype has undergone four major revisions. The final drawing as represented here was made following an all-day meeting at which experts from education and business examined and provided critiques to the entire tree. Some changes may still be made before the tree is quantified for critical paths.

5.0 ANALYSIS OF THE PROTOTYPE TREE

This section will cover some general findings from the fault tree at its present stage of development. The tree as it stands now should be considered incomplete in that several branches could be developed to a greater depth of resolution with additional time and research. There is also no implication that the inputs at each level cover all the possibilities. A box labeled "other" could well accompany most of the inputs to OR gates.

5.1 Reading the tree

The critical undesired event has two inputs summed through an OR gate. Gate A1 (failures of inadequate preparation) has five inputs, also through an OR gate; Gate A2 (other reasons) has three inputs, also through an OR gate. These eight events can also be divided roughly into two time phases: events preceding a job application, and events coexistent with it. The events under Gate A1 could be considered faults internal to the system; those under Gate A2, external to the system.

The tree should be read from the top down, noting at each level whether events are inputs to AND or OR gates. Examples of special gates and their interpretation are:

a. C1 (inhibit gate). Any one of the failure events stated as inputs could cause the failure above given the condition that the speech and/or language function was not compensated for. This condition can be converted to a constant probability.

b. I1 (matrix gate). Each failure condition listed in the box beside the gate (teachers, materials, time, etc.) could be caused by *any one* of the three events below the gate.

c. B3 (sequential OR gate). Event 1 occurs in time *before* either event 2 or 3 or 4. But at Gate C7, event 1 comes before event 2 *or* event 3, and events 2 *or* 3 must precede event 4.

d. F16 (conditional AND gate). Given the constant probability that the appropriate training program is too far from the student's home, the coexistence of the events "no adequate transportation available" *and* "unable to move closer to work" will cause "failure to enter appropriate training program."

e. Houses under Gate H1. The event "family language is non-English," although not *in itself* a failure event, is a basic input which can cause the fault event "faulty learning due to inadequate language models in the home."

5.2 Major findings

a. It is evident that the problem of adequate preparation for employment and the process of employment itself are more complex than is often assumed. This is not a simple problem, and the most effective solutions are likely not to be simple ones.

b. The need for oral communication skills appears in several parts of the tree as logical inputs, and failures in oral communication development will probably constitute critical modes. Another set of events appearing in several branches relates to teaching strategies, particularly the adequate setting forth of objectives, and strategies providing for individual differences in rates, styles, and modes of learning. The need for both oral communication skills and for more effective individualization of instruction has been frequently cited, but the tree clarifies the precise relationships of these needs to occupational preparation deficiencies, and defines the problems in considerable depth.

c. The tree demonstrates the need for very careful diagnosis of student abilities, knowledge and skills in relationship to occupational guidance and training, and equate feedback to the student at each point. This includes the gathering of baseline data as an aid to curriculum construction.

d. A majority of the 330+ events at the ends of the branches lead straight to the top of the tree through OR gates. In effect, then, we have a single thread analysis, in which any event at the bottom of the tree can be thought of as the same as the critical undesired event with which the tree started. Two paths illustrating this point can be traced through Gates A1, B2, C5, D10, E12, and F11; and through Gates A2, B7, C20, D33, E42, F35, G30, H21, I5, and J3. This means that either the event "no model of working adult in family" or "job information comes too late for applicant" could be considered the same as the top undesired event.

From a technical standpoint, such a tree may be viewed as representing a very "unsafe" system, with few features built in which would provide alternative ways of coping with problems or of monitoring possible hazardous events. It may well be that in complex social problems, it is impossible to prevent "failures;" but it should be possible to design a system such that the unfortunate results of such failures would be minimized.

e. Some interesting relationships show up between failures of the decision-making ability (necessary for adequate career choice), low self-esteem, negative environmental press, and speech reticence. There is also a relationship between low self-esteem, reading problems, learning problems, and decision-making. The fault tree pinpoints the locus for the application of research findings to developing solutions.

As a matter of fact, important research has been done on the relationships between anxiety and decision-making, anxiety and speech reticence, reticence and decision-making, reticence and vocational choice. All of these factors show up as interrelated in various parts of the tree.

f. There appear to be two predominant configurations in the system represented by the tree: a pervasive information network, and sets of action or decision points. Most of the failure modes can be described as (1) breakdowns in information or communication, or (2) inadequacies related to desired changes in behavior.

In the first category, there should be noted the following types of events: failures of information input (no input, inadequate input, distorted input, obsolete input, etc.); failures of processing the input data (failures of sensing, perception, association, memory, retrieval of information, etc.), or failures of output (decision-making, transfer, etc.).

In the second category appear those failures related to training: the training is either non-existent or inadequate or obsolete, etc.; or the subject fails the training for a variety of causes. In other words, the desired behavior changes fail to occur at all, or fail to occur to the extent and in the manner desired.

If most of the tree can be viewed in the light of the above two paradigms, it becomes evident that solutions should be aimed at answering two major questions: (1) Who or what should be clearly responsible for the various types of input and action related to the failure modes? and (2) What measures should be taken to assure that the input, processing, and output from any parts of the system stand in clear relationship to each other?

An example can be taken from the area of job information as input to the student. Proceeding on the assumption that in a well-regulated system, success is not dependent upon chance or miracles, it is then necessary to specify clearly the responsibilities for collection, retrieval, and dissemination of all kinds of data regarding occupations, requirements, current job openings, future possibilities, and the like. When vocational guidance and placement are considered everyone's responsibility, then it becomes no one's job. Similarly with either general or specific training, decisions need to be made regarding the public school's role vis-à-vis that of junior colleges, private training institutions, industry, etc. These decisions should be based upon considerations of cost/effectiveness in the broad sense. The tree clearly shows the necessity for more effective interfacing of schools at all levels with business, industry, labor, government, and the community.

Regarding the second question, it becomes obvious that the schools need to do much more to be aware of and prevent failures related broadly to the processing of data. That is, it should be the school's concern not only to raise the quality of input to the student, but to take all necessary measures to insure that every student is able to process that input to the maximum advantage. In essence this means radical changes in instruction to set up criterion measures for achievement rather than normative ones, and to build instruction on the best known ways of providing for individual abilities in reaching the criteria. In some student bodies at the present time, from 50 percent to 75 percent of the students would have to be considered rejects of the system, based on present achievement tests, reading ability, and so on.

g. The failure modes related to factors other than preparation should not be considered exhaustive, but are representative of the obstacles most often encountered. In the present economic and social climate, of Alameda County at least, the likelihood of getting a job with possibilities for advancement is certainly directly related to adequate preparation. Research needs to be done, however, on the actual extent to which failure to be employed relates to economic factors, union requirements, racial and other discrimination, and technological change. It needs no fault tree to know that

5.2 Major findings

hundreds of skilled technical jobs are going begging at a time when thousands of inadequately skilled workers are unemployed. But the precise extent of occurrence of these and other constraints has not been documented.

In the area of job application and placement, data gathered in the process of construction of the tree disclosed that the business of dissemination of job opening information was so fragmented among private and public agencies that the job hunter has to be highly motivated and informed to know where to look.[10] The tree implies this problem, but a redrawing might delineate it more clearly.

5.3 Some implications

In considering the implications of fault tree analysis, it should be noted that any human system will evidence many more single-thread modes of failure at a higher probability of occurrence than a well-designed hardware system. In space vehicles, for instance, the components are engineered for high reliability, and safety features are built in at every step as much as possible. Likewise, the people manning such machines are in as good physical and psychological condition as possible. Any errors, then, can be cut to a minimum through careful training and system safety engineering.

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[10] As this report went to press, a newspaper article reported that the mayors in Alameda County are considering a joint interagency effort to coordinate job placement for minority and disadvantaged persons. Oakland Tribune, October 4, 1968.

In "people problems," however, especially in education, we start with the full spectrum of possibilities -- physically, mentally, psychologically, and socially. Furthermore, not only is it difficult to specify the "products" that should be the outcome of an educational system, but errors in the system multiply with time. The high school graduate or dropout applies for a job with a background of years of growing, learning, and feeling which only incidentally prepare him for employment. Problems relating to his environment, early development, and subsequent twelve years of schooling serve as a kind of undifferentiated background providing him with the baggage with which he now encounters the problem of employment.

An examination of the tree will show that where AND gates occur, there is often the situation in which it is possible to derive the information, training, or other input from more than one source, usually a source outside of the school. Those other sources, however, have a low probability of occurrence for most of the target population being considered in drawing the tree.

The point being stressed here, then, is that the tree clarifies the need for many more "safety" factors in the educational system than are now evident.

Any redesign of the system should consider carefully the necessity for developing solutions that will take care of the failure events in more than one branch of the tree. Since it is apparent that considerable interaction exists among the subsystems and among the components of subsystems, solutions should aim at (1) identifying those relationships, and (2) providing for more effective attack on interacting variables.

5.4 Summary

In summary, the prototype tree as it stands affords a considerable basis for a careful look at any given current educational system concerned with the parameters of occupational preparation. Although many of the failure modes delineated have been known to some degree by educators and other concerned people, the tree provides a visual display of major problems, defines each in some depth, and exhibits relationships at the subsystem and component level.

6.0 EVALUATION OF FAULT TREE ANALYSIS AS AN EDUCATIONAL RESEARCH AND PLANNING TECHNIQUE

At the point to which fault tree analysis has now been developed for educational problems, it is not possible to predict its ultimate usefulness to educational planners. Certainly the state of the art is not yet at the point where its full potential can be unequivocally demonstrated. Certain features are apparent even now, however.

6.1 Use of expertise

The tree as it stands can profitably be used as the basis for discussion with experts from the various areas indicated -- teachers, principals, curriculum coordinators, reading and speech experts, psychologists, learning theorists, employers, union officials, and so on. Discussions can be directed toward evaluating the tree for completeness and accuracy, identifying those failure modes for which solutions are now available, and identifying those areas for which solutions are lacking.

The tree has already demonstrated its usefulness as a communicative tool. During the later revisions of the tree, it was found that expert opinion often differed markedly on the degree to which given input failures resulted in a specific output. In spite of such disagreements, it was found that experts could be brought to focus successfully on one branch of the tree at a time, departing from global generalities and bringing the discussion to specifics. When this happened, it was possible to redefine the problem in order to account for the range of opinions, and ultimately to arrive at real agreement.

6.2 Evaluation of programs

Innovative programs related to any of the parameters of occupational preparation can be examined to see whether program objectives are clearly stated to indicate those aspects of the problem to be attacked, and whether the methods proposed will actually do the job.

The tree has also made it possible to put differing perceptions of the problem into perspective. It often occurs that individuals working in one area become so specialized that they tend to see only one aspect of a situation as being of major importance. For example, the following have been cited as major solutions: setting up special math classes for noncollege-bound students, training disadvantaged students to make out job applications and behave properly in job interviews, and setting up special vocational-technical high schools, among others. Whether any or all of these measures should be taken depends on the probability that the needs met by the programs suggested are in fact those needs with the highest failure incidence -- and that fact is not yet known. Yet it is possible to find sincere workers in the field who consider only one solution and ignore the relevance of other possibilities.

6.3 Design completeness

The tree also demonstrates that it may not be the main ingredients of the program that fail, but the irritation built up by many apparently peripheral problems. This often occurs when the planning lacks adequate consideration of such matters as logistics and the integration of support systems. Two examples come to mind.

6.3 Design completeness

In one instance, an otherwise well-planned summer workshop for teachers who were to initiate an innovative program nearly foundered because of repeated small annoyances -- TV equipment failing to work, constant change of room assignments, and an underestimation by the speakers as to the degree of sophistication of the group.

In another instance, a program of bussing black students to a largely white school was almost wrecked because the bussed students arrived at school in a highly charged and irritated state of mind. It was discovered almost by accident that one of the bus drivers constantly made demeaning and deprecating statements to and about the black students. The situation was remedied by providing mothers to ride on the busses. Any new program purporting to provide a solution to a problem needs to be examined for built-in factors that would raise worse problems than the program solves.

Since fault tree analysis can identify and specify such possibilities, program planners can design in secondary supports, monitors, remedial action, and the like. The more such failures can be prevented, the greater the chance for success of the program. The question can be asked, "If this event were to happen because of such and such causes, what measures can we fall back on?" The analysis thus focuses attention on aspects that might otherwise be overlooked. Since this can all be done in the planning stage, the teachers in the program can be freed to concentrate on instruction, their prime responsibility.

6.3 Design completeness

If fault tree analysis is conducted in stages during the design of a change or a new program, it can alert the planners to areas where only OR gates exist. Redesign of the system could provide for AND gates and inhibit conditions that are in essence safety factors.

6.4 Resource allocation

Finally, it is widely felt that most educational problems could be solved with adequate funds. But money alone will not solve such problems, as experience with the poverty program and compensatory education has proved. What is needed are better bases for decisions as to where to allocate funds. When large sums of money are spent only to remediate conditions for which the underlying causes still exist, the problem will continue, even grow. Developmental as well as remedial programs must be given priority consideration. And where direct attack on underlying causes is beyond the capability of the system, at least safeguards can be built in to prevent the situation from having catastrophic results.

Fault tree analysis can enable school administrators to analyze the cost/effectiveness of alternate programs. In a non-cost/effective system, the options open to teachers and students are random, not planned. Fault tree analysis permits evaluation of information flow within and between subsystems, and uncovers points of communication breakdown.

Although there are many technical problems yet to be solved before fault tree analysis as an educational tool can be used to best advantage, new rules and paradigms will be developed as needed to guide the construction of the tree and to aid in its evaluation.

APPENDIX

A PROTOTYPE FAULT TREE APPLIED TO THE GENERAL PROBLEM, "PREPARATION FOR THE WORLD OF WORK"

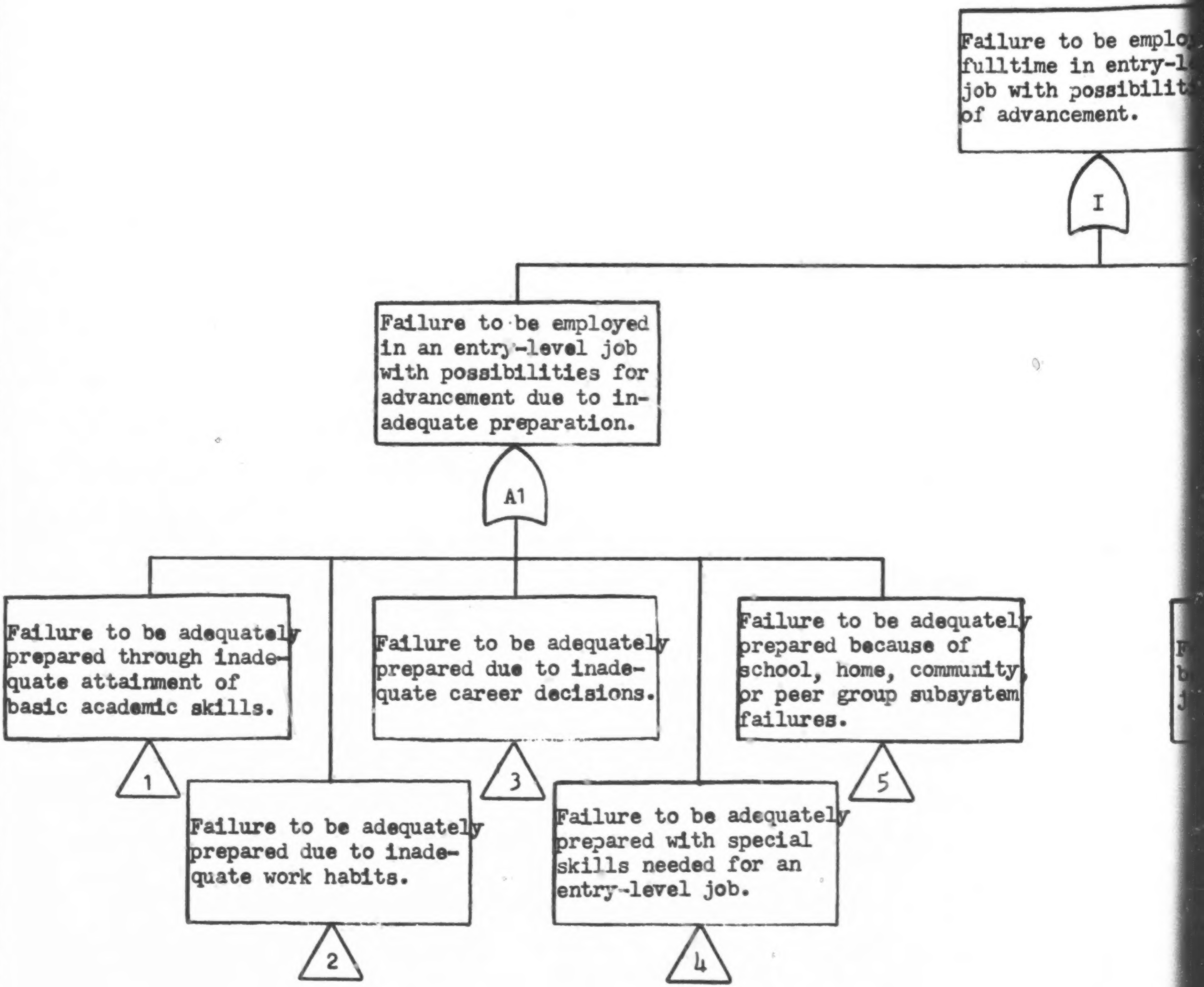
ERRATA

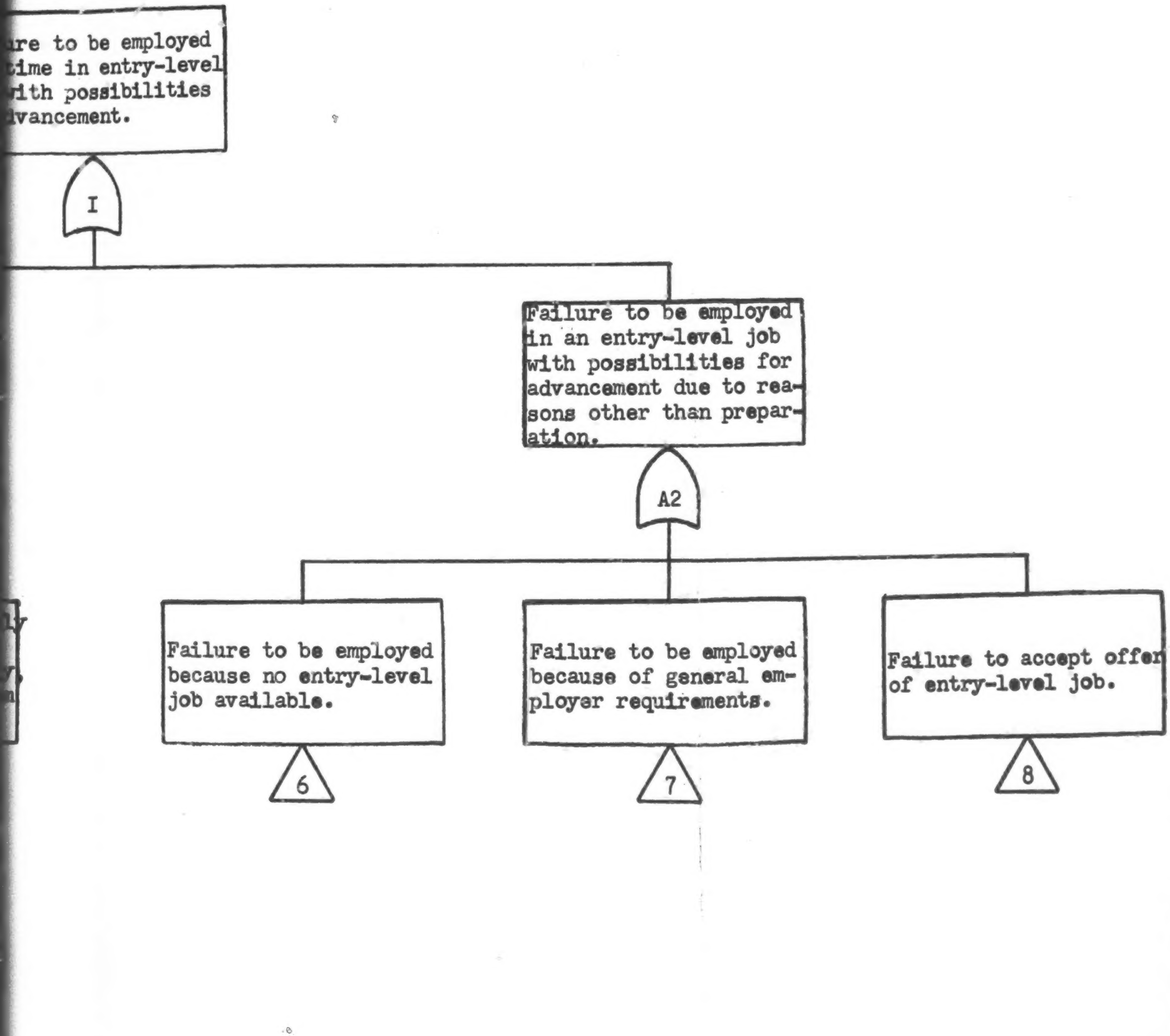
Page A3 - Change gate E9 to E10
Change gate E10 to F9

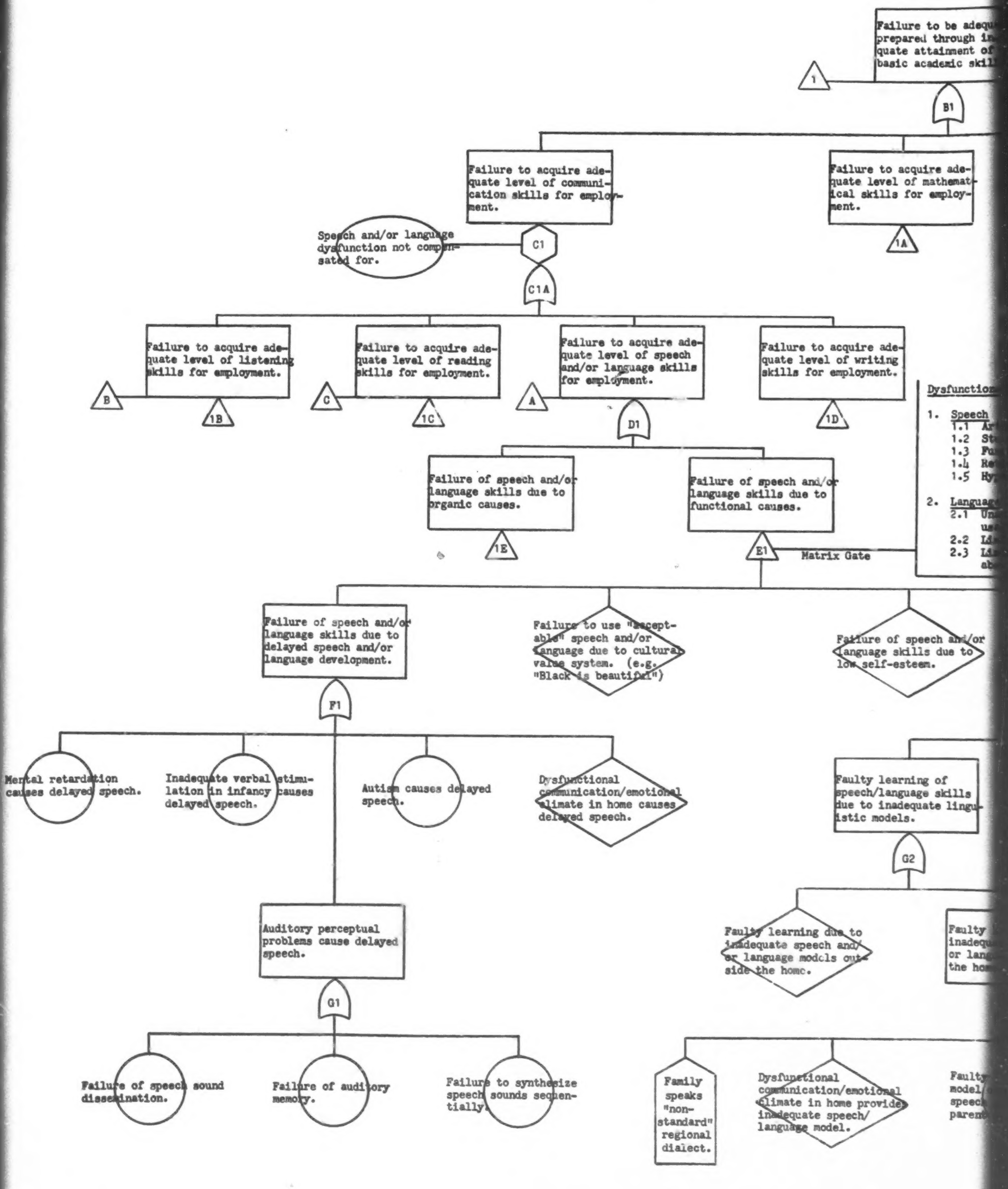
A7 - Reverse the boxes above gates E15 and E16

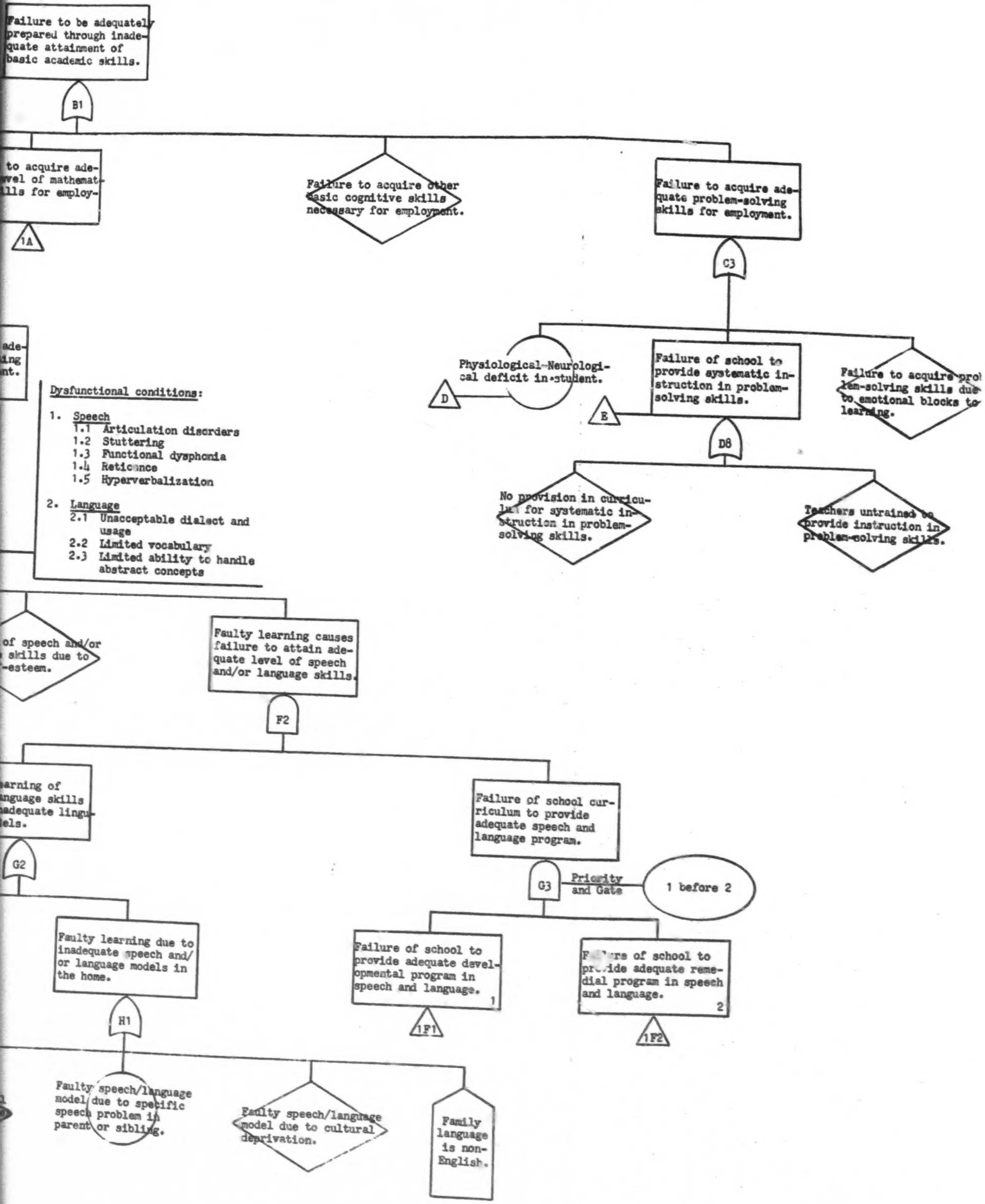
A8 - Change gate D13 from OR to AND
Change gate E20 in lower right corner to E21

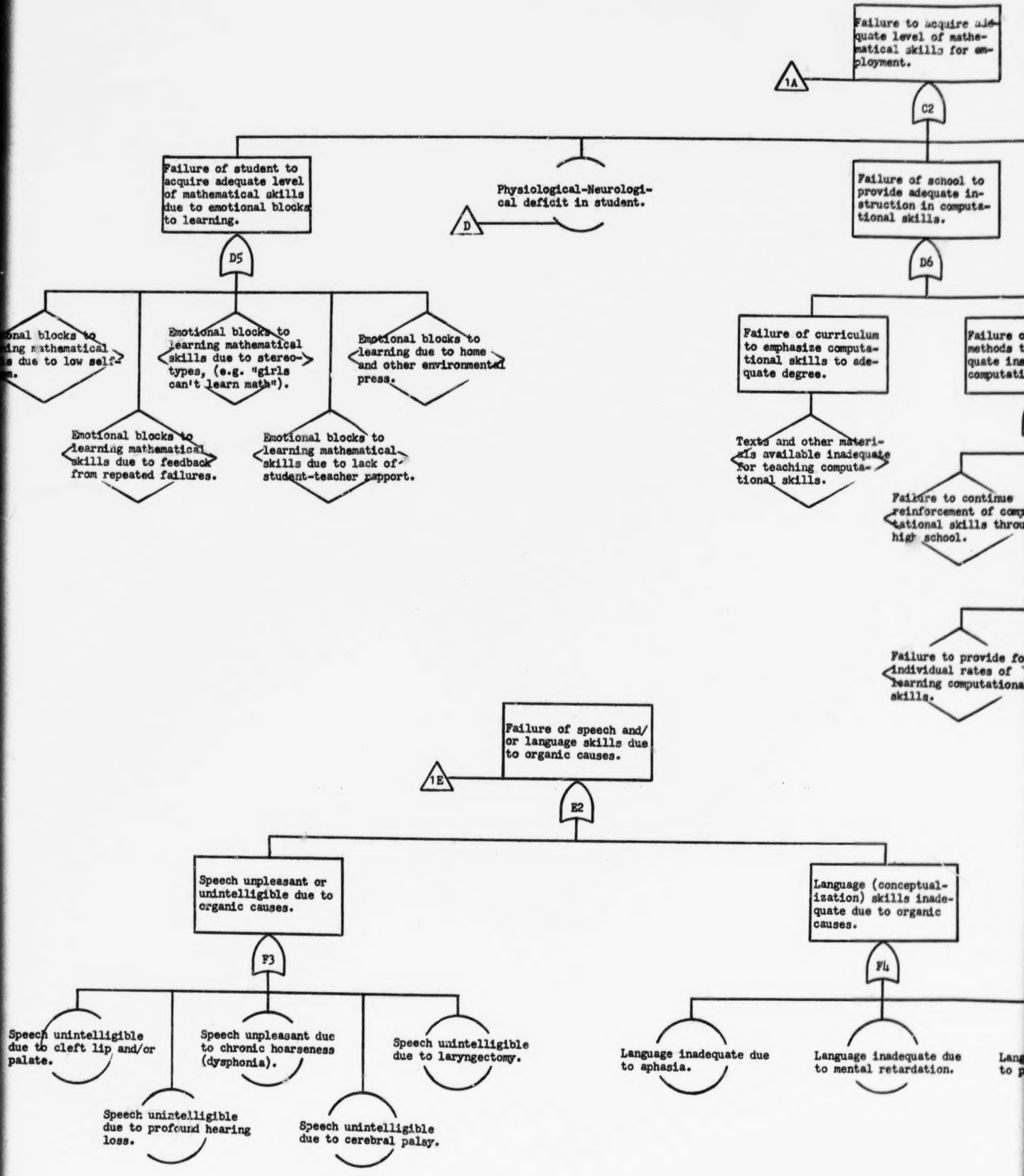
A17 - Change gate F36 from OR to AND

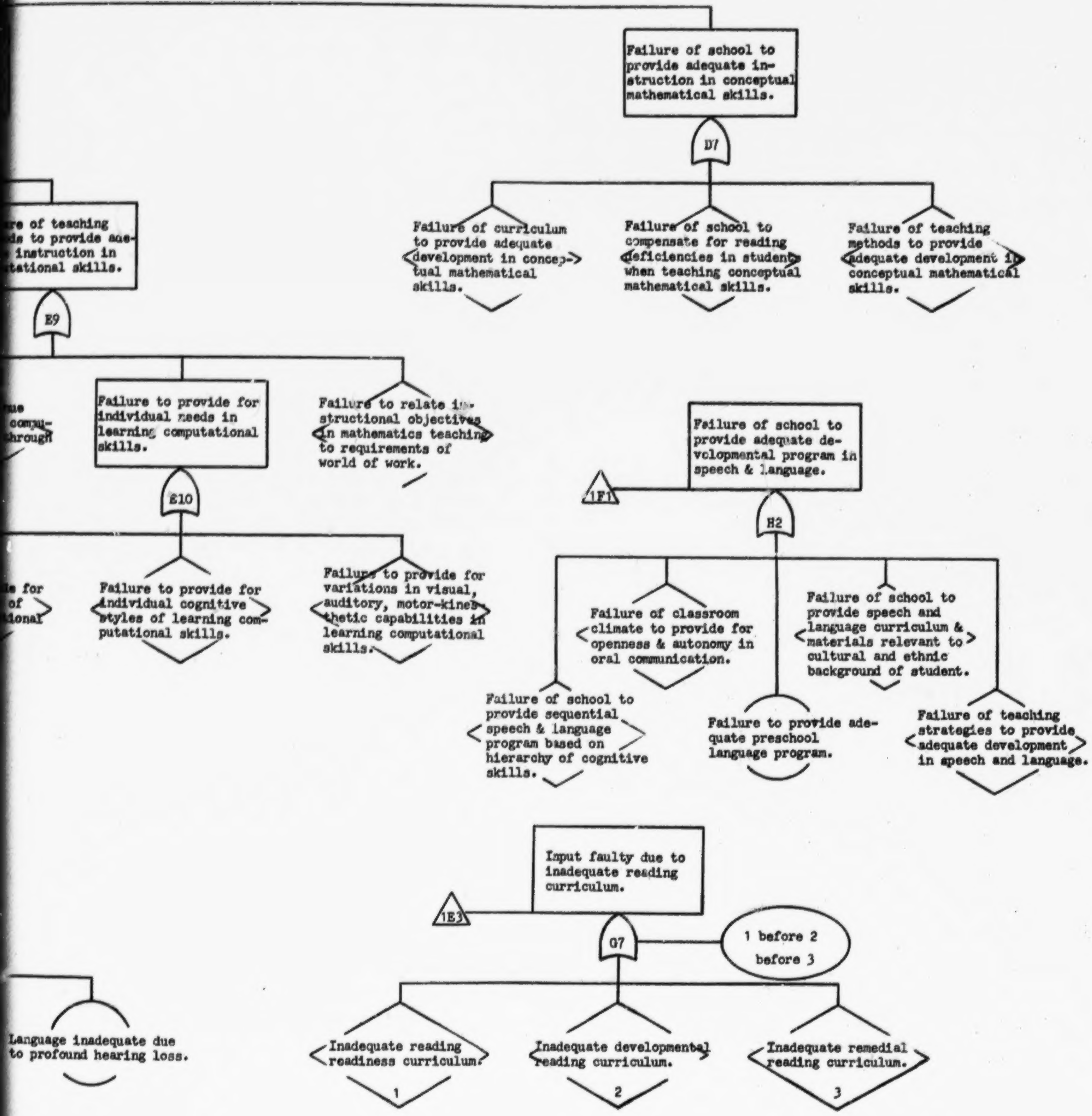

Failure to be emplo
fulltime in entry-l
job with possibilit
of advancement.
I
Failure to be employed in an entry-level job with possibilities for advancement due to inadequate preparation.
A1
Failure to be adequately prepared through inadequate attainment of basic academic skills.
1
Failure to be adequately prepared due to inadequate work habits.
2
Failure to be adequately prepared due to inadequate career decisions.
3
Failure to be adequately prepared with special skills needed for an entry-level job.
4
Failure to be adequately prepared because of school, home, community, or peer group subsystem failures.
5
F
b
J

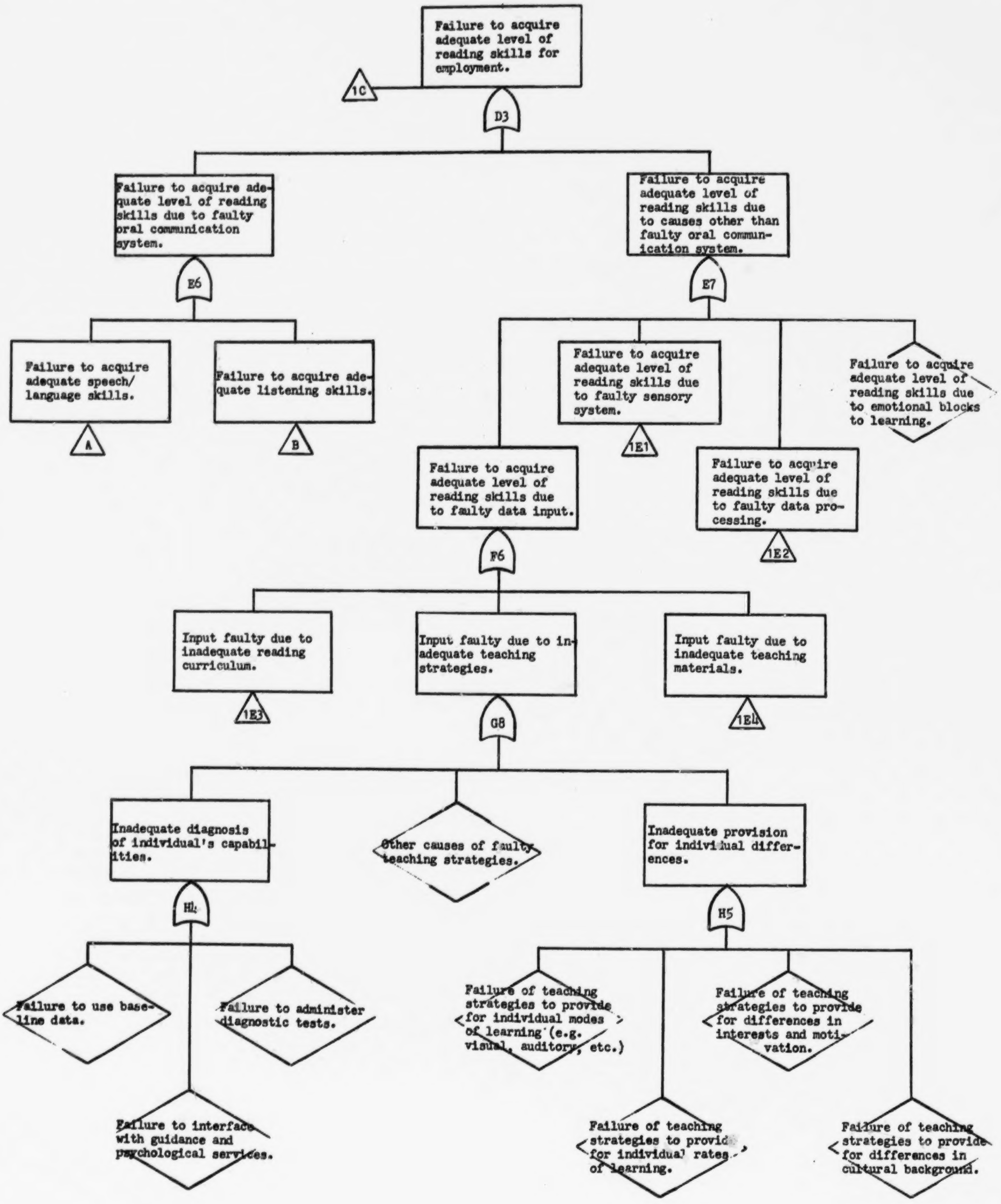

ure to be employed
time in entry-level
with possibilities
dvancement.
I
Failure to be employed in an entry-level job with possibilities for advancement due to reasons other than preparation.
A2
Failure to be employed because no entry-level job available.
6
Failure to be employed because of general employer requirements.
7
Failure to accept offer of entry-level job.
8
ly
y,
n

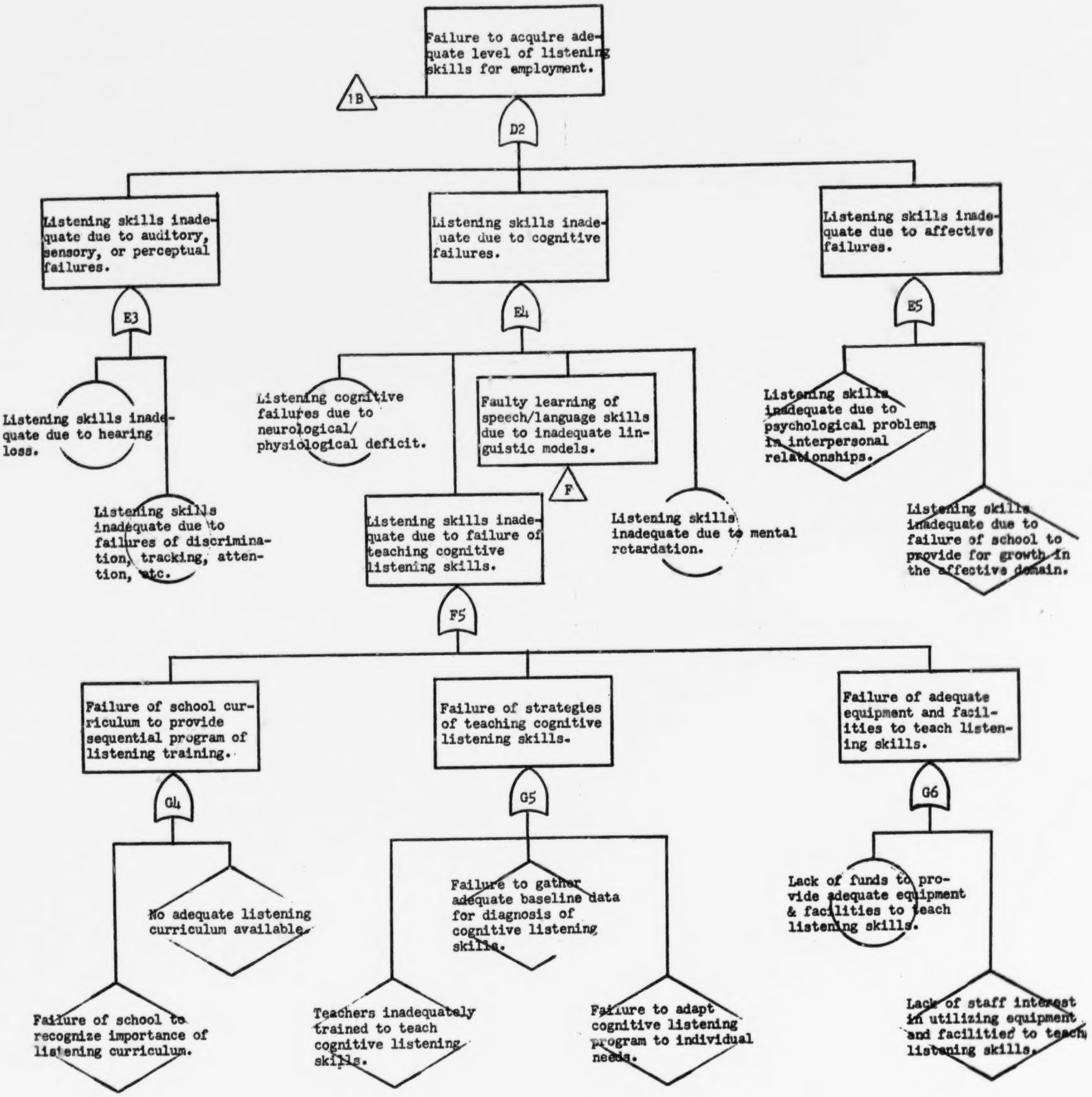

Failure to be adequ
prepared through in
quate attainment of
basic academic skil
1
B1
Failure to acquire adequate level of communication skills for employment.
Failure to acquire adequate level of mathematical skills for employment.
1A
Speech and/or language dysfunction not compensated for.
C1
C1A
Failure to acquire adequate level of listening skills for employment.
B
1B
Failure to acquire adequate level of reading skills for employment.
C
1C
Failure to acquire adequate level of speech and/or language skills for employment.
A
D1
Failure to acquire adequate level of writing skills for employment.
1D
Dysfunction
1. Speech
1.1 Ar
1.2 St
1.3 Fu
1.4 Re
1.5 Hy
2. Languag
2.1 Un
us
2.2 Li
2.3 Li
ab
Failure of speech and/or language skills due to organic causes.
1E
Failure of speech and/or language skills due to functional causes.
E1
Matrix Gate
Failure of speech and/or language skills due to delayed speech and/or language development.
Failure to use "acceptable" speech and/or language due to cultural value system. (e.g. "Black is beautiful")
Failure of speech and/or language skills due to low self-esteem.
F1
Mental retardation causes delayed speech.
Inadequate verbal stimulation in infancy causes delayed speech.
Autism causes delayed speech.
Dysfunctional communication/emotional climate in home causes delayed speech.
Faulty learning of speech/language skills due to inadequate linguistic models.
G2
Auditory perceptual problems cause delayed speech.
G1
Faulty learning due to inadequate speech and/or language models outside the home.
Faulty
inadequ
or lang
the hom
Failure of speech sound dissemination.
Failure of auditory memory.
Failure to synthesize speech sounds sequentially.
Family speaks "non-standard" regional dialect.
Dysfunctional communication/emotional climate in home provides inadequate speech/language model.
Faulty
model/
speech
paren

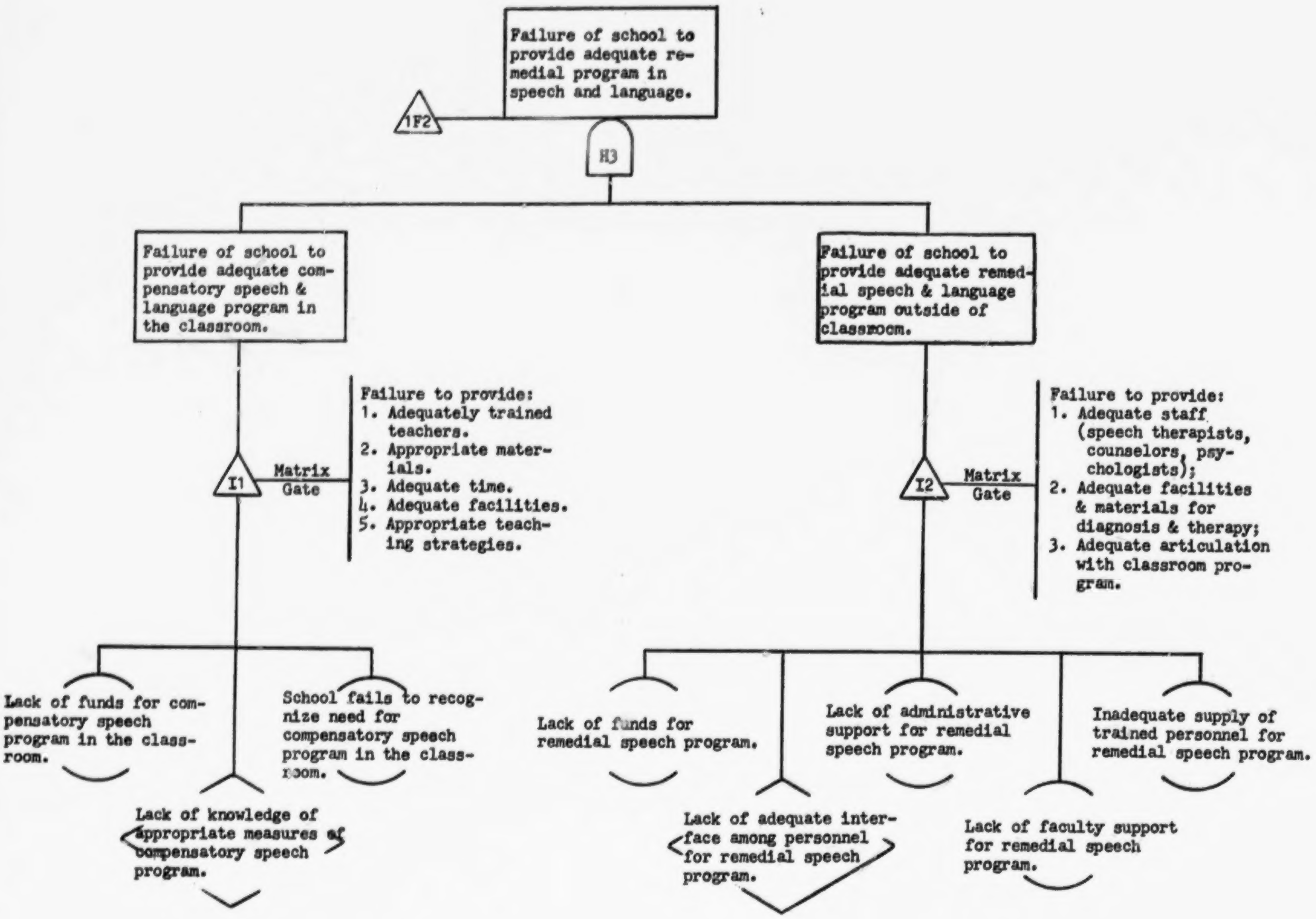

Failure to be adequately prepared through inadequate attainment of basic academic skills.
B1
to acquire ade-
vel of mathemat-
lls for employ-
1A
Failure to acquire other basic cognitive skills necessary for employment.
Failure to acquire adequate problem-solving skills for employment.
C3
ade-
ing
nt.
Physiological-Neurological deficit in student.
D
Failure of school to provide systematic instruction in problem-solving skills.
E
Failure to acquire problem-solving skills due to emotional blocks to learning.
D8
No provision in curriculum for systematic instruction in problem-solving skills.
Teachers untrained to provide instruction in problem-solving skills.
Dysfunctional conditions:
1. Speech
1.1 Articulation disorders
1.2 Stuttering
1.3 Functional dysphonia
1.4 Reticence
1.5 Hyperverbalization
2. Language
2.1 Unacceptable dialect and usage
2.2 Limited vocabulary
2.3 Limited ability to handle abstract concepts
of speech and/or
skills due to
-esteem.
Faulty learning causes failure to attain adequate level of speech and/or language skills.
F2
earning of
anguage skills
adequate lingu-
els.
G2
Failure of school curriculum to provide adequate speech and language program.
G3
Priority and Gate
1 before 2
Faulty learning due to inadequate speech and/or language models in the home.
Failure of school to provide adequate developmental program in speech and language.
1
Failure of school to provide adequate remedial program in speech and language.
2
1F1
1F2
H1
Faulty speech/language model due to specific speech problem in parent or sibling.
Faulty speech/language model due to cultural deprivation.
Family language is non-English.

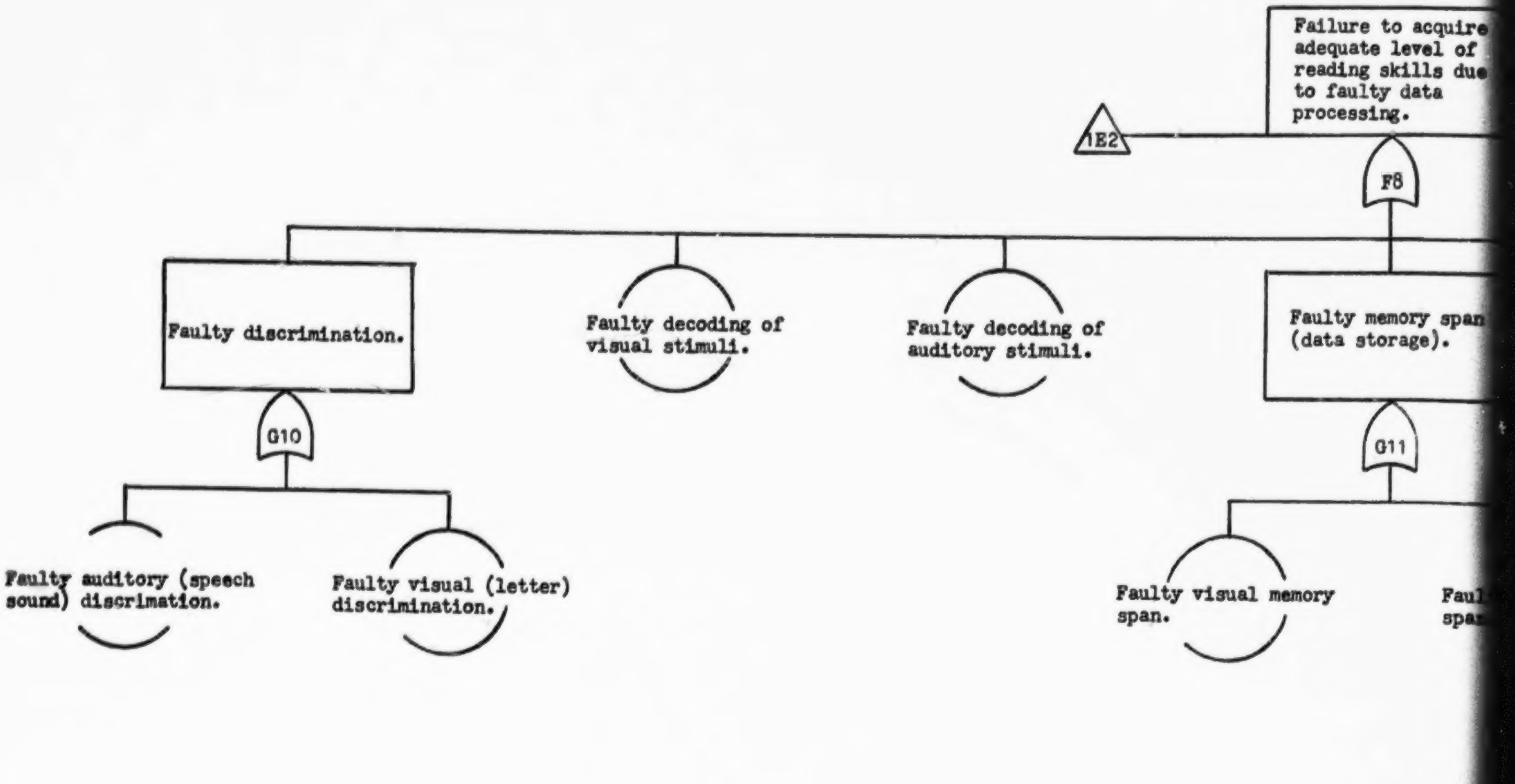

Failure to acquire adequate level of mathematical skills for employment.
1A
C2
Failure of student to acquire adequate level of mathematical skills due to emotional blocks to learning.
Physiological-Neurological deficit in student.
D
Failure of school to provide adequate instruction in computational skills.
D5
D6
onal blocks to
ning mathematical
s due to low self-
m.
Emotional blocks to learning mathematical skills due to stereotypes, (e.g. "girls can't learn math").
Emotional blocks to learning due to home and other environmental press.
Emotional blocks to learning mathematical skills due to feedback from repeated failures.
Emotional blocks to learning mathematical skills due to lack of student-teacher rapport.
Failure of curriculum to emphasize computational skills to adequate degree.
Failure o
methods t
quate ins
computati
Texts and other materials available inadequate for teaching computational skills.
Failure to continue reinforcement of comp
tational skills throu
high school.
Failure to provide fo
individual rates of
learning computationa
skills.
Failure of speech and/or language skills due to organic causes.
1E
E2
Speech unpleasant or unintelligible due to organic causes.
Language (conceptualization) skills inadequate due to organic causes.
F3
F4
Speech unintelligible due to cleft lip and/or palate.
Speech unpleasant due to chronic hoarseness (dysphonia).
Speech unintelligible due to laryngectomy.
Speech unintelligible due to profound hearing loss.
Speech unintelligible due to cerebral palsy.
Language inadequate due to aphasia.
Language inadequate due to mental retardation.
Lang
to p

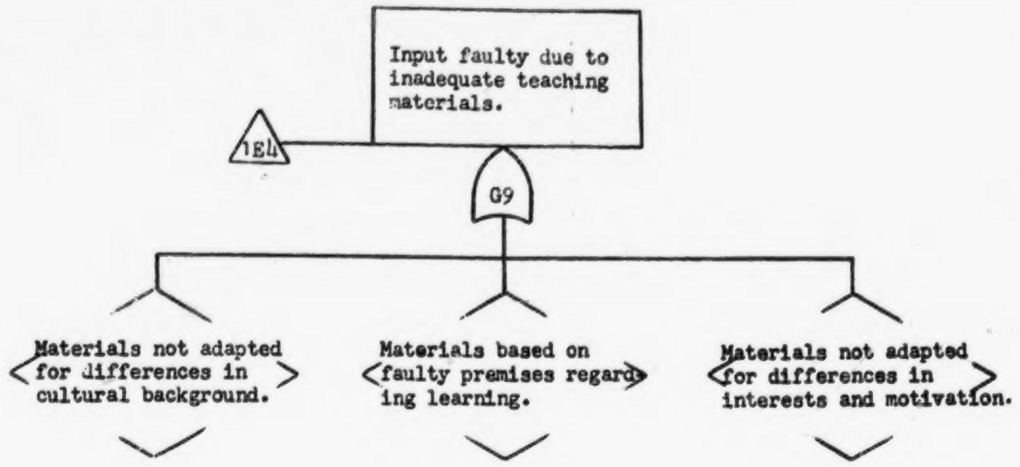

Failure of school to provide adequate instruction in conceptual mathematical skills.
D7
Failure of curriculum to provide adequate development in conceptual mathematical skills.
Failure of school to compensate for reading deficiencies in students when teaching conceptual mathematical skills.
Failure of teaching methods to provide adequate development in conceptual mathematical skills.
re of teaching
ds to provide ade-
instruction in
tational skills.
E9
ue
compu-
through
Failure to provide for individual needs in learning computational skills.
Failure to relate instructional objectives in mathematics teaching to requirements of world of work.
E10
e for
of
tional
Failure to provide for individual cognitive styles of learning computational skills.
Failure to provide for variations in visual, auditory, motor-kinesthetic capabilities in learning computational skills.
Failure of school to provide adequate developmental program in speech & language.
1F1
H2
Failure of classroom climate to provide for openness & autonomy in oral communication.
Failure of school to provide speech and language curriculum & materials relevant to cultural and ethnic background of student.
Failure of school to provide sequential speech & language program based on hierarchy of cognitive skills.
Failure to provide adequate preschool language program.
Failure of teaching strategies to provide adequate development in speech and language.
Input faulty due to inadequate reading curriculum.
1E3
G7
1 before 2 before 3
Inadequate reading readiness curriculum.
1
Inadequate developmental reading curriculum.
2
Inadequate remedial reading curriculum.
3
Language inadequate due to profound hearing loss.

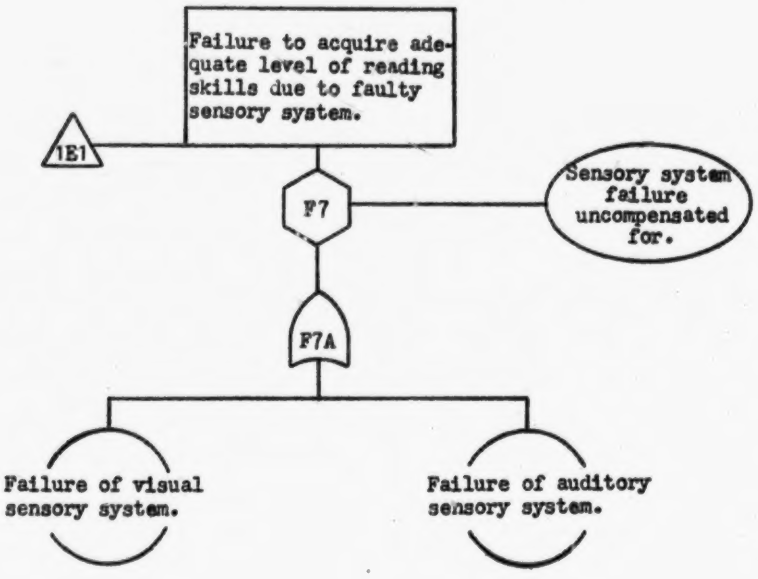

Failure to acquire adequate level of reading skills for employment.
1C
D3
Failure to acquire adequate level of reading skills due to faulty oral communication system.
Failure to acquire adequate level of reading skills due to causes other than faulty oral communication system.
E6
E7
Failure to acquire adequate speech/ language skills.
A
Failure to acquire adequate listening skills.
B
Failure to acquire adequate level of reading skills due to faulty sensory system.
1E1
Failure to acquire adequate level of reading skills due to emotional blocks to learning.
Failure to acquire adequate level of reading skills due to faulty data input.
Failure to acquire adequate level of reading skills due to faulty data processing.
1E2
F6
Input faulty due to inadequate reading curriculum.
1E3
Input faulty due to inadequate teaching strategies.
Input faulty due to inadequate teaching materials.
1E4
G8
Inadequate diagnosis of individual's capabilities.
Other causes of faulty teaching strategies.
Inadequate provision for individual differences.
H4
H5
Failure to use baseline data.
Failure to administer diagnostic tests.
Failure to interface with guidance and psychological services.
Failure of teaching strategies to provide for individual modes of learning (e.g. visual, auditory, etc.)
Failure of teaching strategies to provide for differences in interests and motivation.
Failure of teaching strategies to provide for individual rates of learning.
Failure of teaching strategies to provide for differences in cultural background.

Failure to acquire adequate level of listening skills for employment.
1B
D2
Listening skills inadequate due to auditory, sensory, or perceptual failures.
Listening skills inadequate due to cognitive failures.
Listening skills inadequate due to affective failures.
E3
E4
E5
Listening skills inadequate due to hearing loss.
Listening skills inadequate due to failures of discrimination, tracking, attention, etc.
Listening cognitive failures due to neurological/physiological deficit.
Faulty learning of speech/language skills due to inadequate linguistic models.
F
Listening skills inadequate due to failure of teaching cognitive listening skills.
Listening skills inadequate due to mental retardation.
Listening skills inadequate due to psychological problems in interpersonal relationships.
Listening skills inadequate due to failure of school to provide for growth in the affective domain.
F5
Failure of school curriculum to provide sequential program of listening training.
Failure of strategies of teaching cognitive listening skills.
Failure of adequate equipment and facilities to teach listening skills.
G4
G5
G6
No adequate listening curriculum available.
Failure of school to recognize importance of listening curriculum.
Failure to gather adequate baseline data for diagnosis of cognitive listening skills.
Teachers inadequately trained to teach cognitive listening skills.
Failure to adapt cognitive listening program to individual needs.
Lack of funds to provide adequate equipment & facilities to teach listening skills.
Lack of staff interest in utilizing equipment and facilities to teach listening skills.

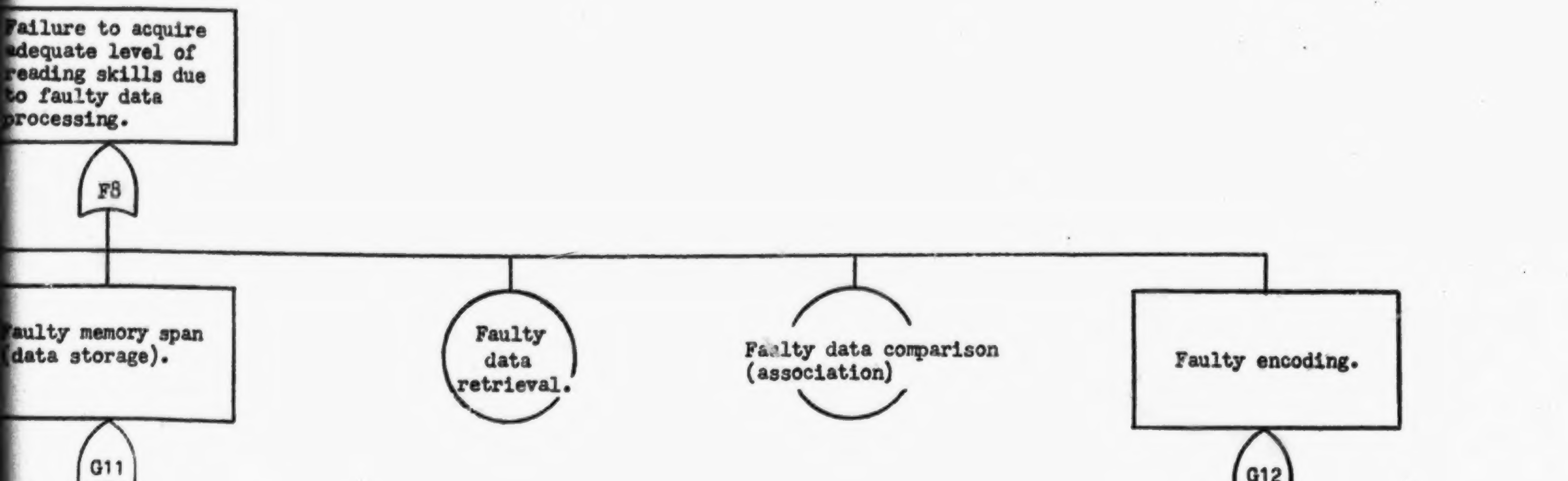

Failure of school to provide adequate remedial program in speech and language.
1F2
H3
Failure of school to provide adequate compensatory speech & language program in the classroom.
Failure of school to provide adequate remedial speech & language program outside of classroom.
I1
Matrix Gate
Failure to provide:
1. Adequately trained teachers.
2. Appropriate materials.
3. Adequate time.
4. Adequate facilities.
5. Appropriate teaching strategies.
I2
Matrix Gate
Failure to provide:
1. Adequate staff (speech therapists, counselors, psychologists);
2. Adequate facilities & materials for diagnosis & therapy;
3. Adequate articulation with classroom program.
Lack of funds for compensatory speech program in the classroom.
School fails to recognize need for compensatory speech program in the classroom.
Lack of knowledge of appropriate measures of compensatory speech program.
Lack of funds for remedial speech program.
Lack of administrative support for remedial speech program.
Inadequate supply of trained personnel for remedial speech program.
Lack of adequate interface among personnel for remedial speech program.
Lack of faculty support for remedial speech program.

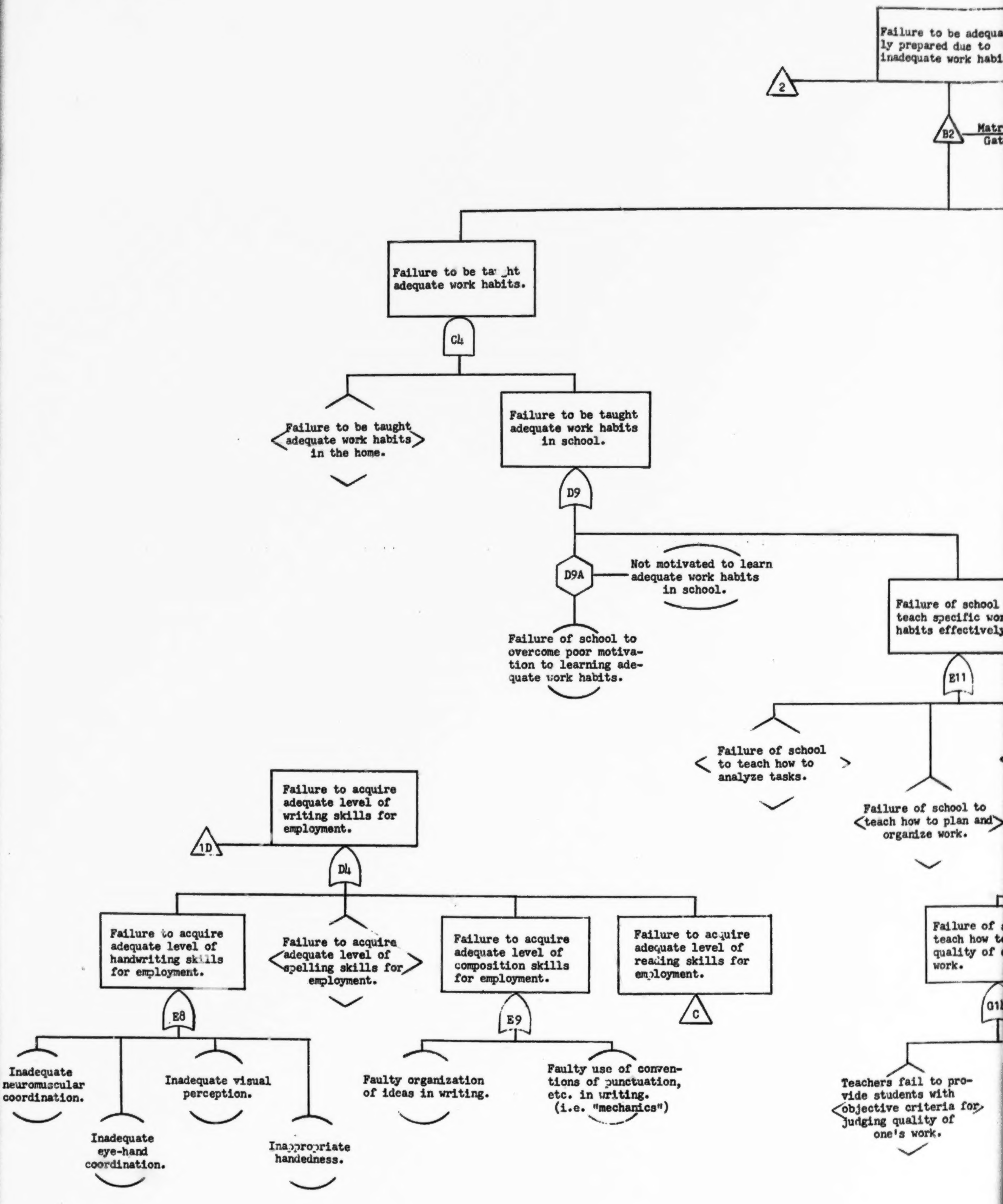

Failure to acquire adequate level of reading skills due to faulty data processing.
1E2
F8
Faulty discrimination.
Faulty decoding of visual stimuli.
Faulty decoding of auditory stimuli.
Faulty memory span (data storage).
G10
G11
Faulty auditory (speech sound) discrimation.
Faulty visual (letter) discrimination.
Faulty visual memory span.

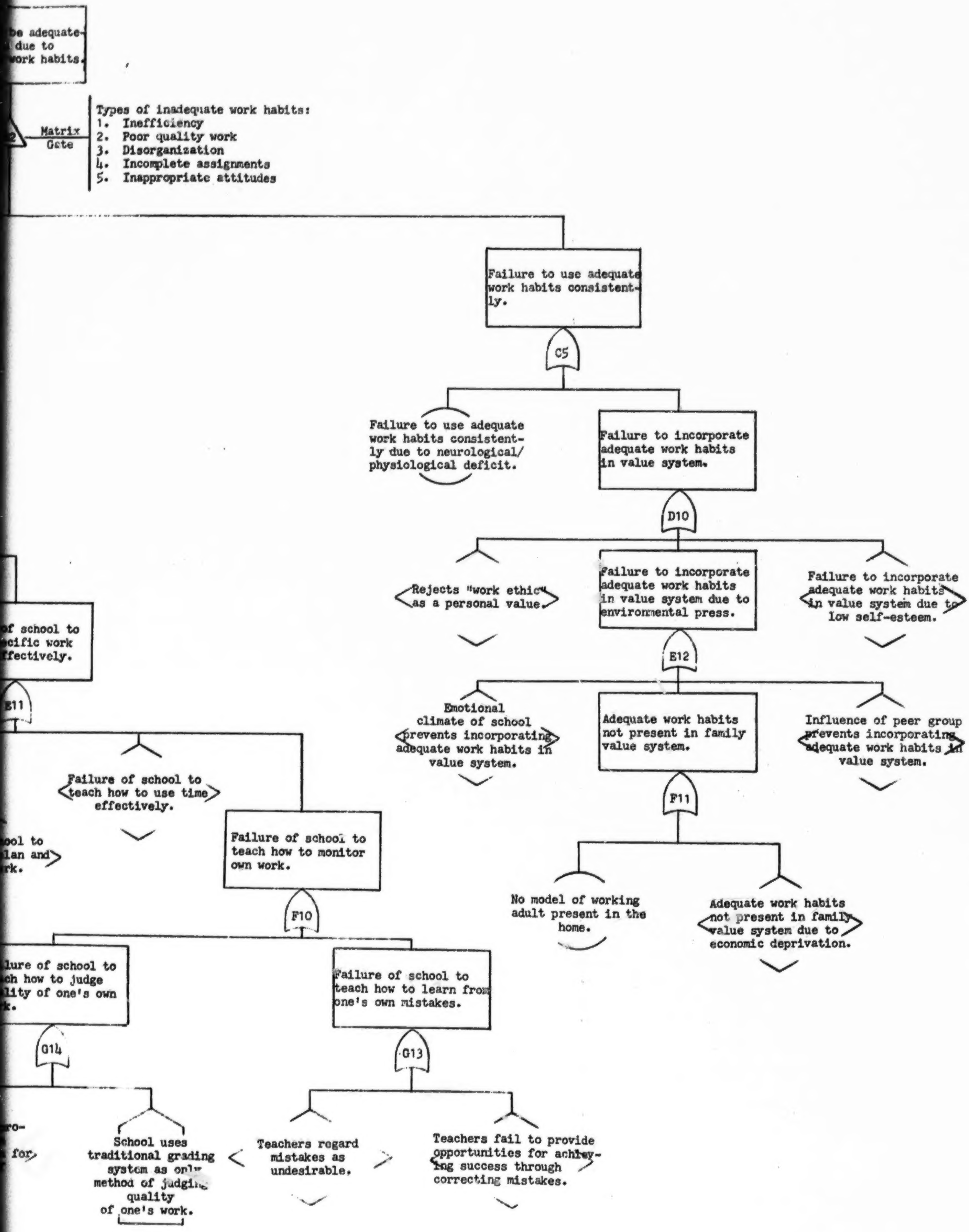

Input faulty due to inadequate teaching materials.
1E4
G9
Materials not adapted for differences in cultural background.
Materials based on faulty premises regarding learning.
Materials not adapted for differences in interests and motivation.

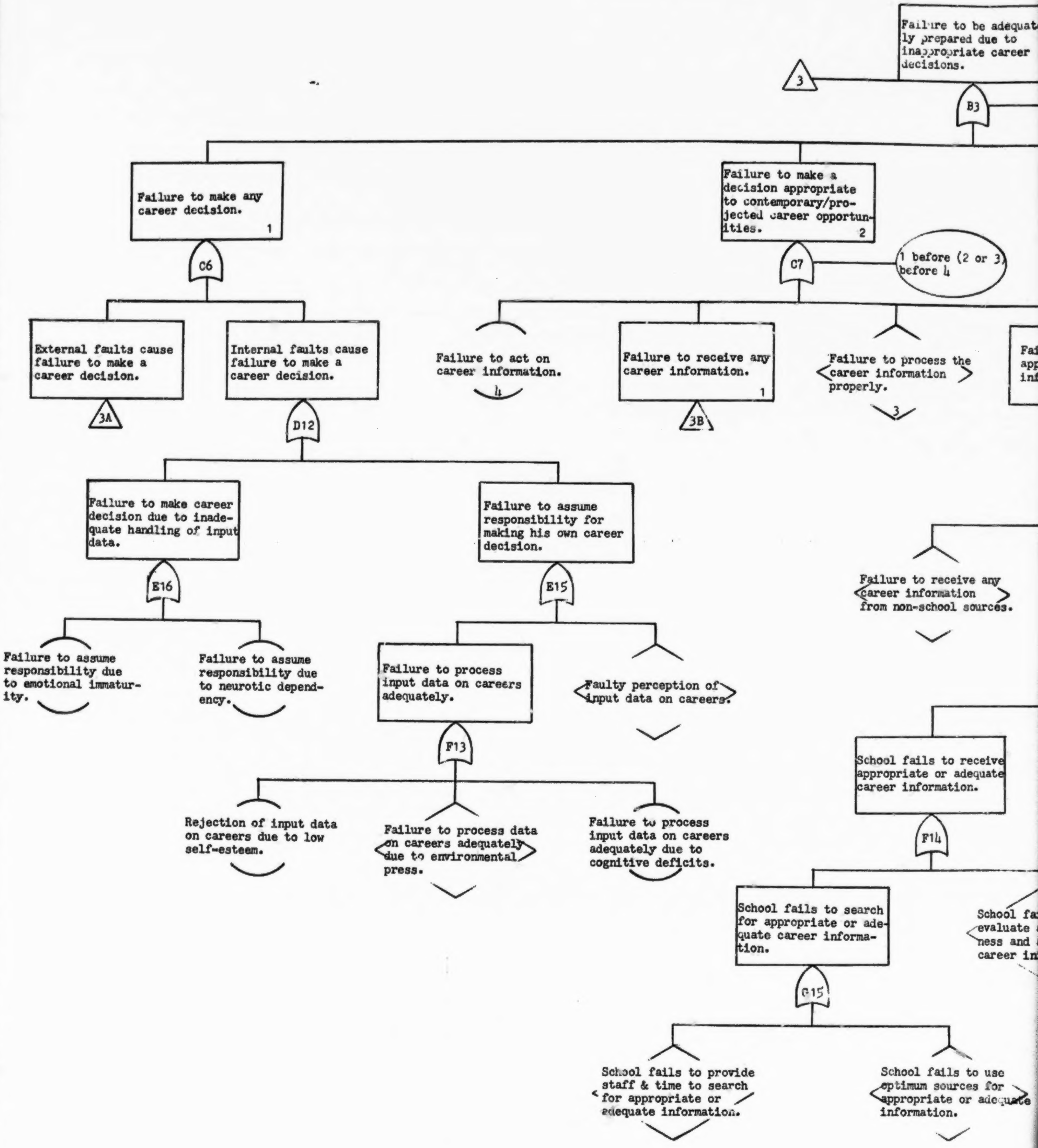

Failure to acquire adequate level of reading skills due to faulty sensory system.
1E1
F7
Sensory system failure uncompensated for.
F7A
Failure of visual sensory system.
Failure of auditory sensory system.

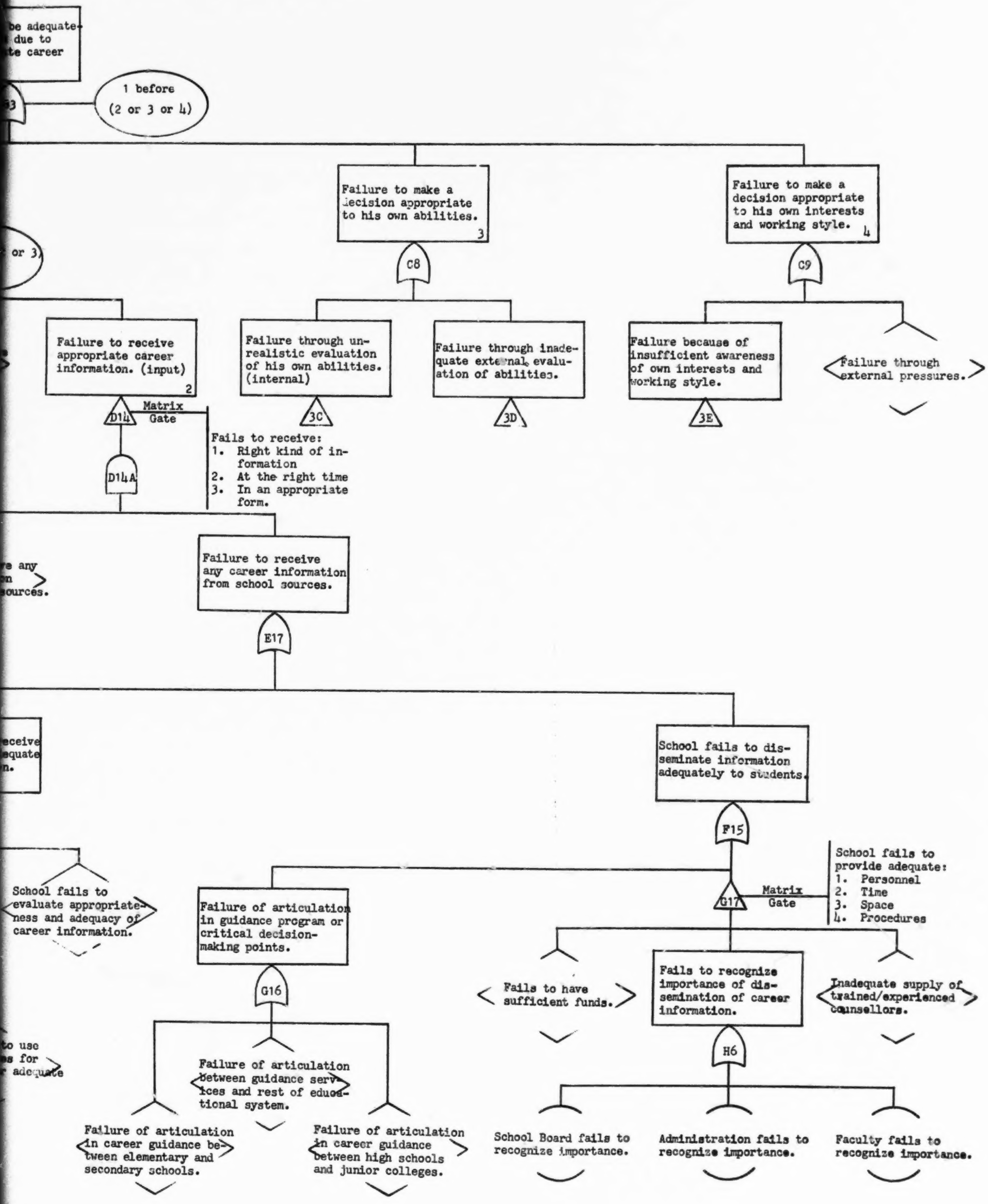
r
ram.

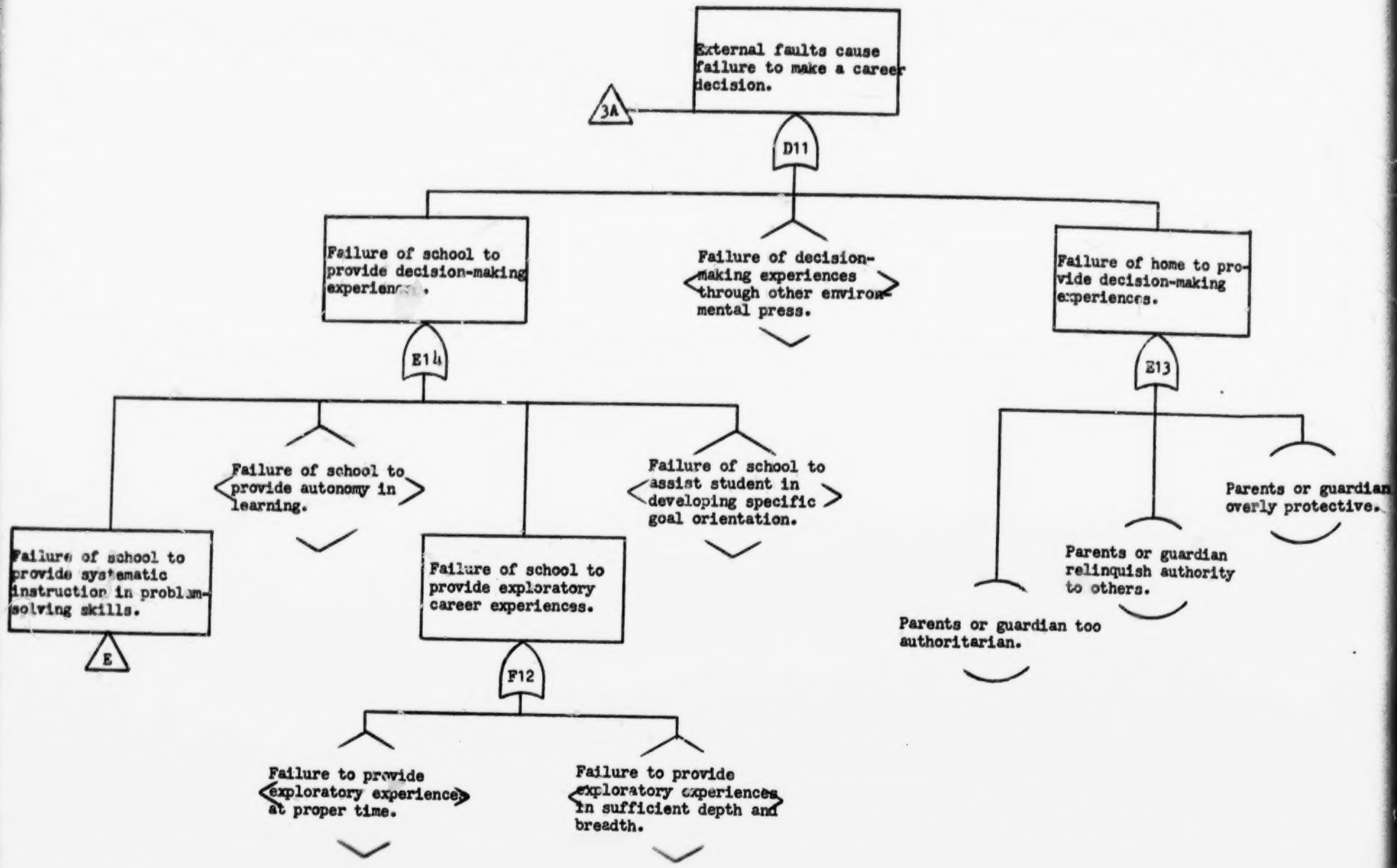

Failure to acquire adequate level of reading skills due to faulty data processing.
F8
Faulty memory span (data storage).
Faulty data retrieval.
Faulty data comparison (association)
Faulty encoding.
G11
ory
Faulty auditory memory span.
G12
Faulty speech encoding.
Faulty motor encoding (writing).

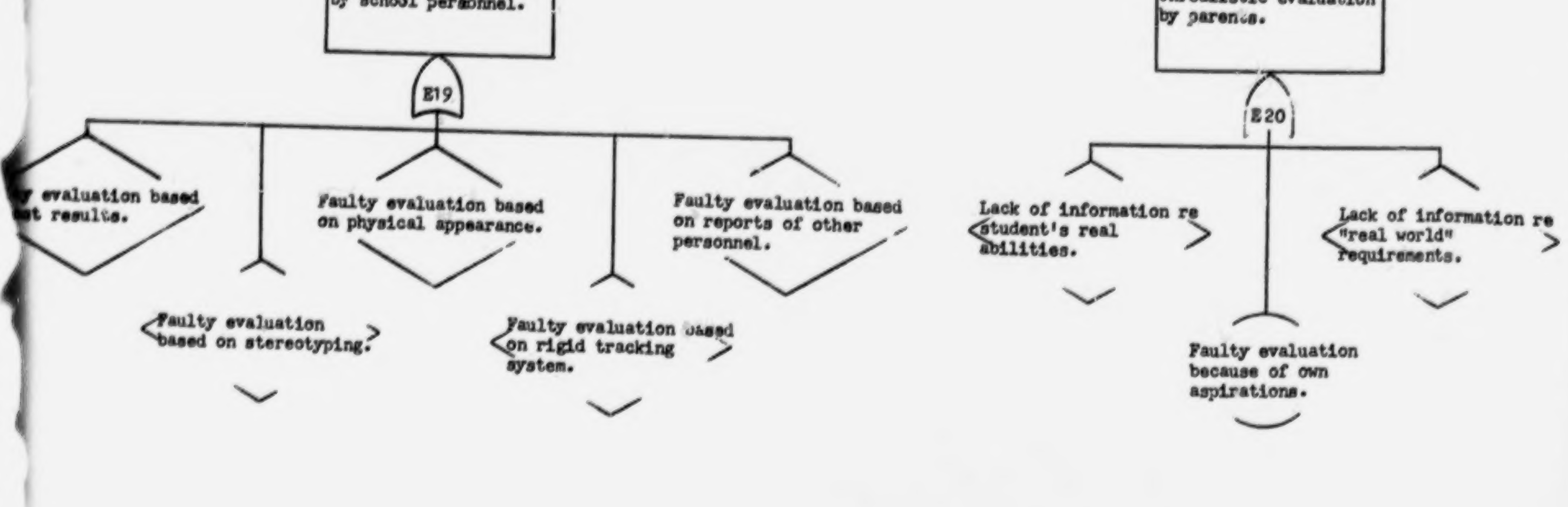

Failure to be adequa
ly prepared due to
inadequate work habi
2
B2
Matr
Gat
Failure to be taught adequate work habits.
C4
Failure to be taught adequate work habits in the home.
Failure to be taught adequate work habits in school.
D9
D9A
Not motivated to learn adequate work habits in school.
Failure of school to overcome poor motivation to learning adequate work habits.
Failure of school
teach specific wor
habits effectivel
E11
Failure of school to teach how to analyze tasks.
Failure of school to teach how to plan and organize work.
Failure of
teach how t
quality of
work.
G1
Teachers fail to provide students with objective criteria for judging quality of one's work.
Failure to acquire adequate level of writing skills for employment.
1D
D4
Failure to acquire adequate level of handwriting skills for employment.
Failure to acquire adequate level of spelling skills for employment.
Failure to acquire adequate level of composition skills for employment.
Failure to acquire adequate level of reading skills for employment.
C
E8
Inadequate neuromuscular coordination.
Inadequate eye-hand coordination.
Inadequate visual perception.
Inappropriate handedness.
E9
Faulty organization of ideas in writing.
Faulty use of conventions of punctuation, etc. in writing. (i.e. "mechanics")

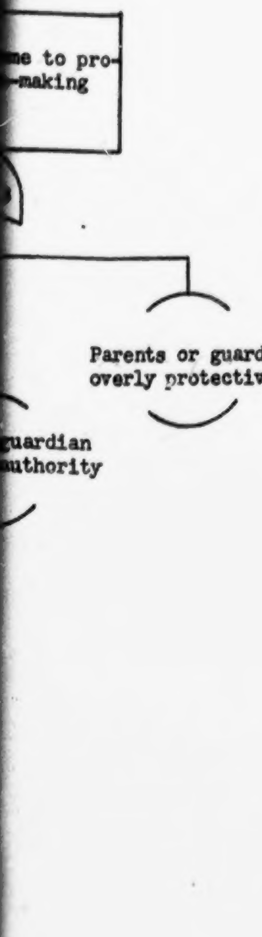

be adequate-
due to
work habits.
Matrix
Gate
Types of inadequate work habits:
1. Inefficiency
2. Poor quality work
3. Disorganization
4. Incomplete assignments
5. Inappropriate attitudes
Failure to use adequate work habits consistently.
C5
Failure to use adequate work habits consistently due to neurological/ physiological deficit.
Failure to incorporate adequate work habits in value system.
D10
Rejects "work ethic" as a personal value.
Failure to incorporate adequate work habits in value system due to environmental press.
Failure to incorporate adequate work habits in value system due to low self-esteem.
E12
Emotional climate of school prevents incorporating adequate work habits in value system.
Adequate work habits not present in family value system.
Influence of peer group prevents incorporating adequate work habits in value system.
F11
No model of working adult present in the home.
Adequate work habits not present in family value system due to economic deprivation.
of school to
ecific work
ffectively.
E11
Failure of school to teach how to use time effectively.
ool to
lan and
rk.
Failure of school to teach how to monitor own work.
F10
ilure of school to
ch how to judge
lity of one's own
k.
Failure of school to teach how to learn from one's own mistakes.
G14
G13
ro-
for
School uses traditional grading system as only method of judging quality of one's work.
Teachers regard mistakes as undesirable.
Teachers fail to provide opportunities for achieving success through correcting mistakes.


Failure to be adequately prepared due to inappropriate career decisions.
3
B3
Failure to make any career decision.
1
C6
Failure to make a decision appropriate to contemporary/projected career opportunities.
2
C7
1 before (2 or 3) before 4
External faults cause failure to make a career decision.
3A
Internal faults cause failure to make a career decision.
D12
Failure to act on career information.
4
Failure to receive any career information.
1
3B
Failure to process the career information properly.
3
Failure to make career decision due to inadequate handling of input data.
E16
Failure to assume responsibility for making his own career decision.
E15
Failure to receive any career information from non-school sources.
Failure to assume responsibility due to emotional immaturity.
Failure to assume responsibility due to neurotic dependency.
Failure to process input data on careers adequately.
F13
Faulty perception of input data on careers.
School fails to receive appropriate or adequate career information.
F14
Rejection of input data on careers due to low self-esteem.
Failure to process data on careers adequately due to environmental press.
Failure to process input data on careers adequately due to cognitive deficits.
School fails to search for appropriate or adequate career information.
G15
School fails to provide staff & time to search for appropriate or adequate information.
School fails to use optimum sources for appropriate or adequate information.


be adequate- due to te career
1 before (2 or 3 or 4)
Failure to make a decision appropriate to his own abilities. 3
C8
Failure to make a decision appropriate to his own interests and working style. 4
C9
or 3)
Failure to receive appropriate career information. (input) 2
Failure through unrealistic evaluation of his own abilities. (internal)
Failure through inadequate external evaluation of abilities.
Failure because of insufficient awareness of own interests and working style.
Failure through external pressures.
D14
Matrix Gate
3C
3D
3E
Fails to receive:
1. Right kind of information
2. At the right time
3. In an appropriate form.
D14A
e any on sources.
Failure to receive any career information from school sources.
E17
eceive equate n.
School fails to disseminate information adequately to students.
F15
School fails to provide adequate:
1. Personnel
2. Time
3. Space
4. Procedures
School fails to evaluate appropriateness and adequacy of career information.
Failure of articulation in guidance program or critical decision-making points.
G17
Matrix Gate
Fails to have sufficient funds.
Fails to recognize importance of dissemination of career information.
Inadequate supply of trained/experienced counsellors.
G16
H6
to use s for adequate
Failure of articulation between guidance services and rest of educational system.
Failure of articulation in career guidance between elementary and secondary schools.
Failure of articulation in career guidance between high schools and junior colleges.
School Board fails to recognize importance.
Administration fails to recognize importance.
Faculty fails to recognize importance.


3A
External faults cause failure to make a career decision.
D11
Failure of school to provide decision-making experiences.
Failure of decision-making experiences through other environmental press.
Failure of home to provide decision-making experiences.
E14
E13
Failure of school to provide autonomy in learning.
Failure of school to assist student in developing specific goal orientation.
Parents or guardian overly protective.
Failure of school to provide systematic instruction in problem-solving skills.
E
Failure of school to provide exploratory career experiences.
Parents or guardian relinquish authority to others.
Parents or guardian too authoritarian.
F12
Failure to provide exploratory experience at proper time.
Failure to provide exploratory experiences in sufficient depth and breadth.


Failure through inadequate external evaluation of abilities.
3D
D16
Unrealistic evaluation by school personnel.
Unrealistic evaluation by parents.
E19
E20
y evaluation based
t results.
Faulty evaluation based on physical appearance.
Faulty evaluation based on reports of other personnel.
Lack of information re student's real abilities.
Lack of information re "real world" requirements.
Faulty evaluation based on stereotyping.
Faulty evaluation based on rigid tracking system.
Faulty evaluation because of own aspirations.



me to pro-
-making
Parents or guardian overly protective.
guardian
authority
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ack of information re
"real world"
equirements.
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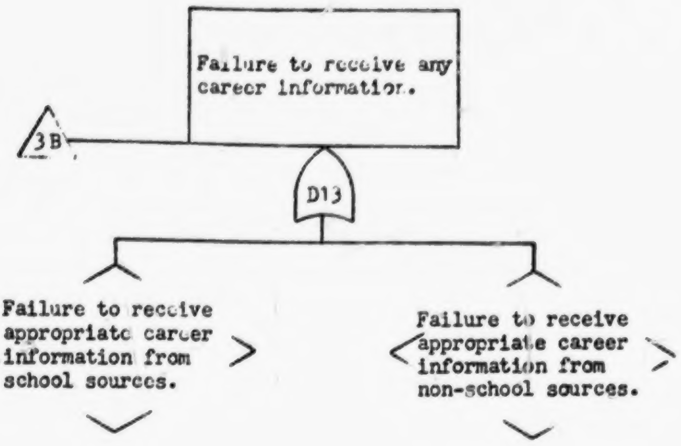
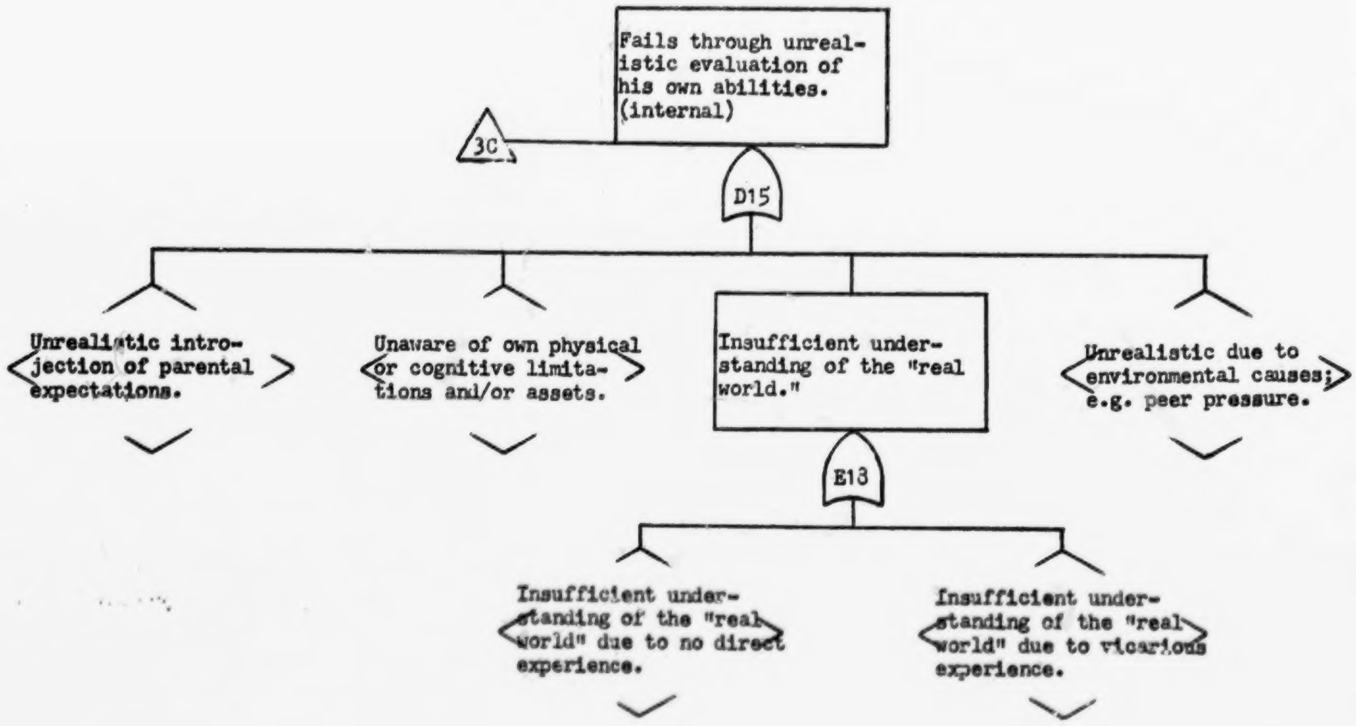
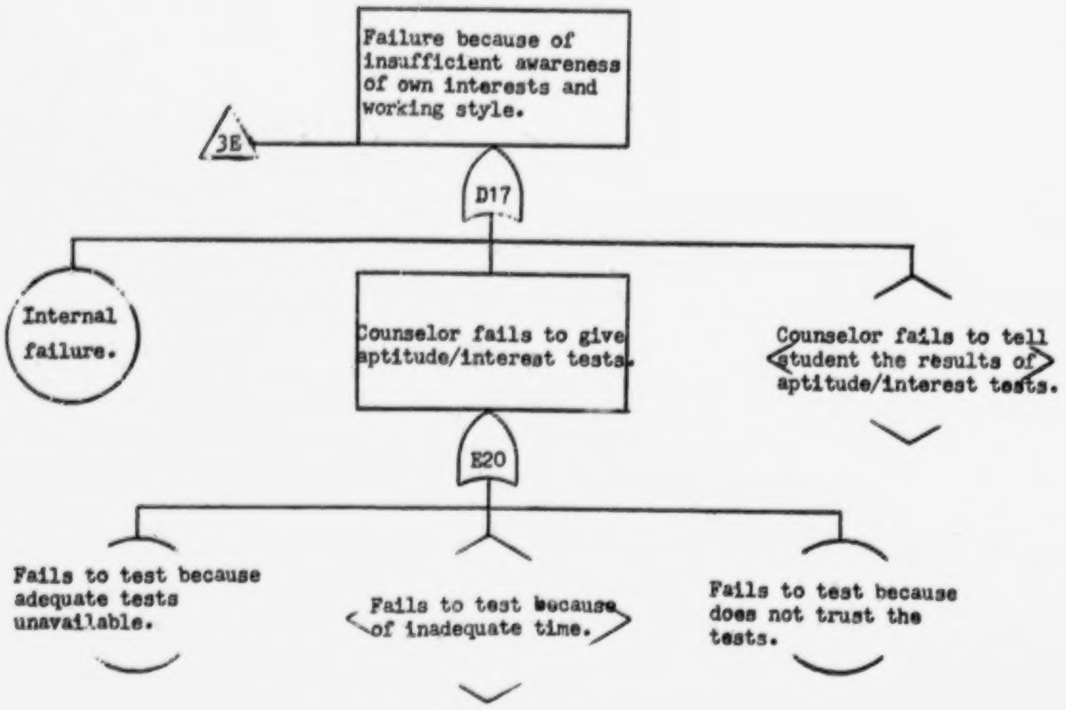


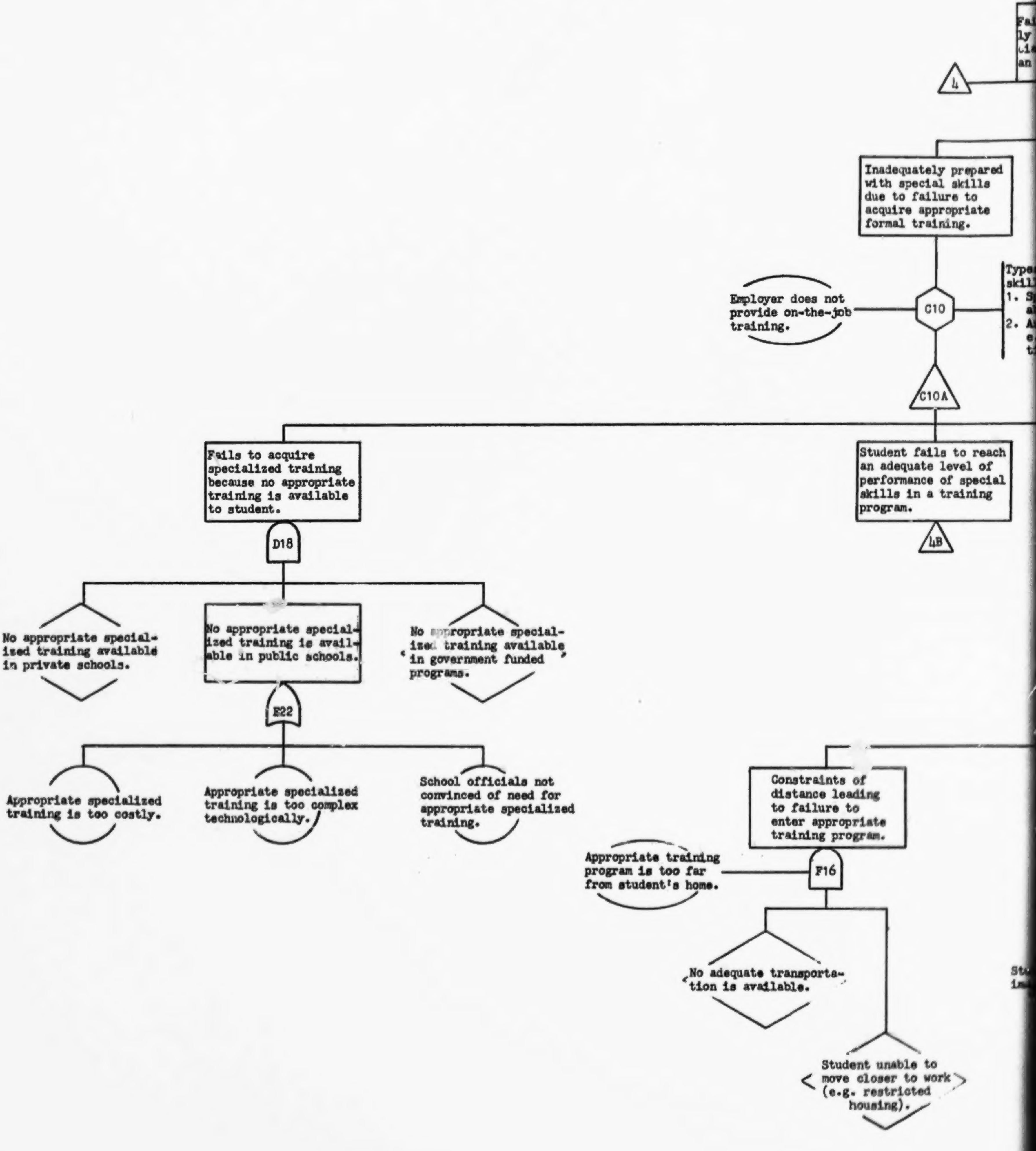
Failure to receive any career information.
3B
D13
Failure to receive appropriate career information from school sources.
Failure to receive appropriate career information from non-school sources.

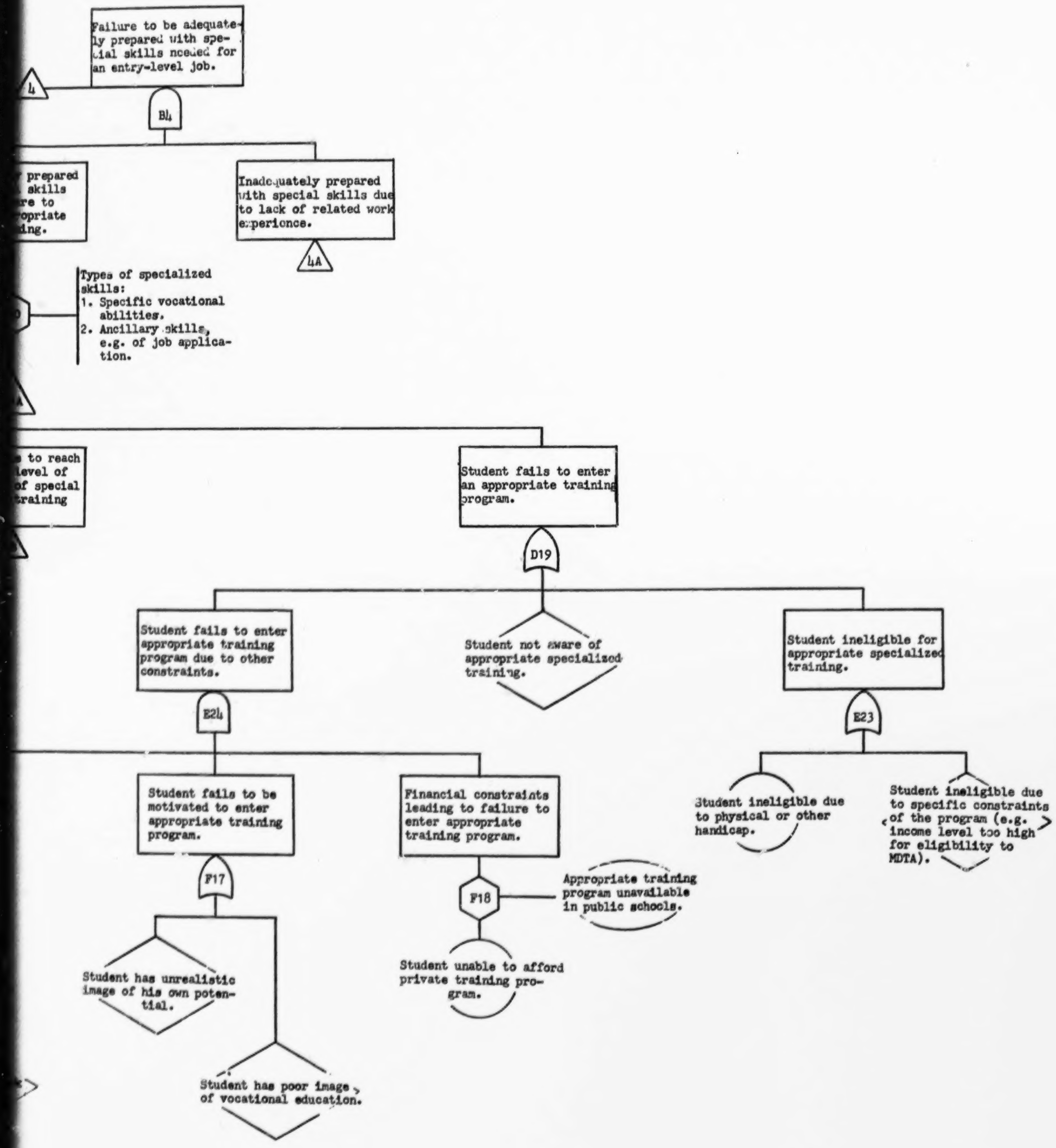


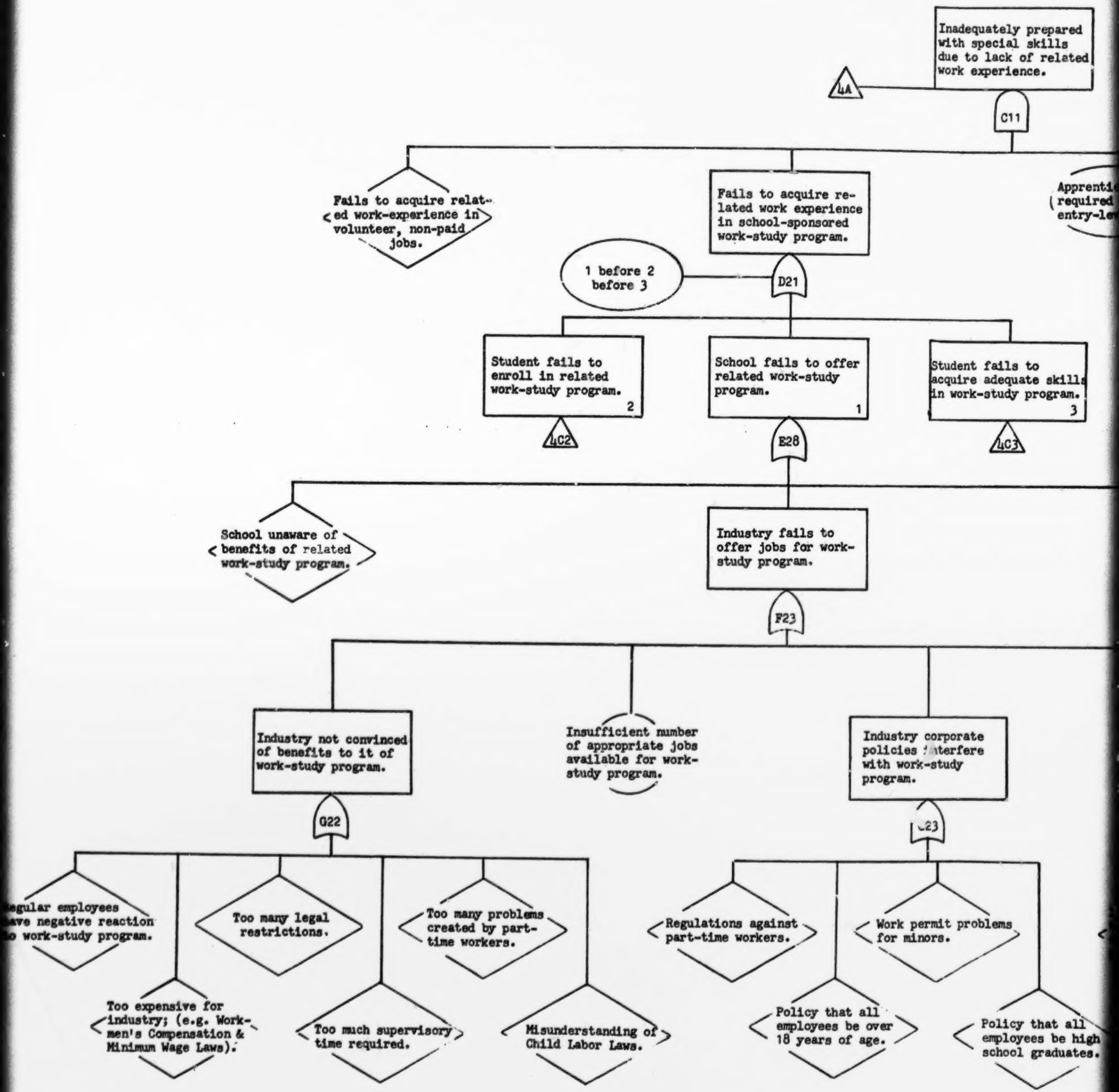
Fails through unrealistic evaluation of his own abilities. (internal)
3C
D15
Unrealistic introjection of parental expectations.
Unaware of own physical or cognitive limitations and/or assets.
Insufficient understanding of the "real world."
Unrealistic due to environmental causes; e.g. peer pressure.
E18
Insufficient understanding of the "real world" due to no direct experience.
Insufficient understanding of the "real world" due to vicarious experience.

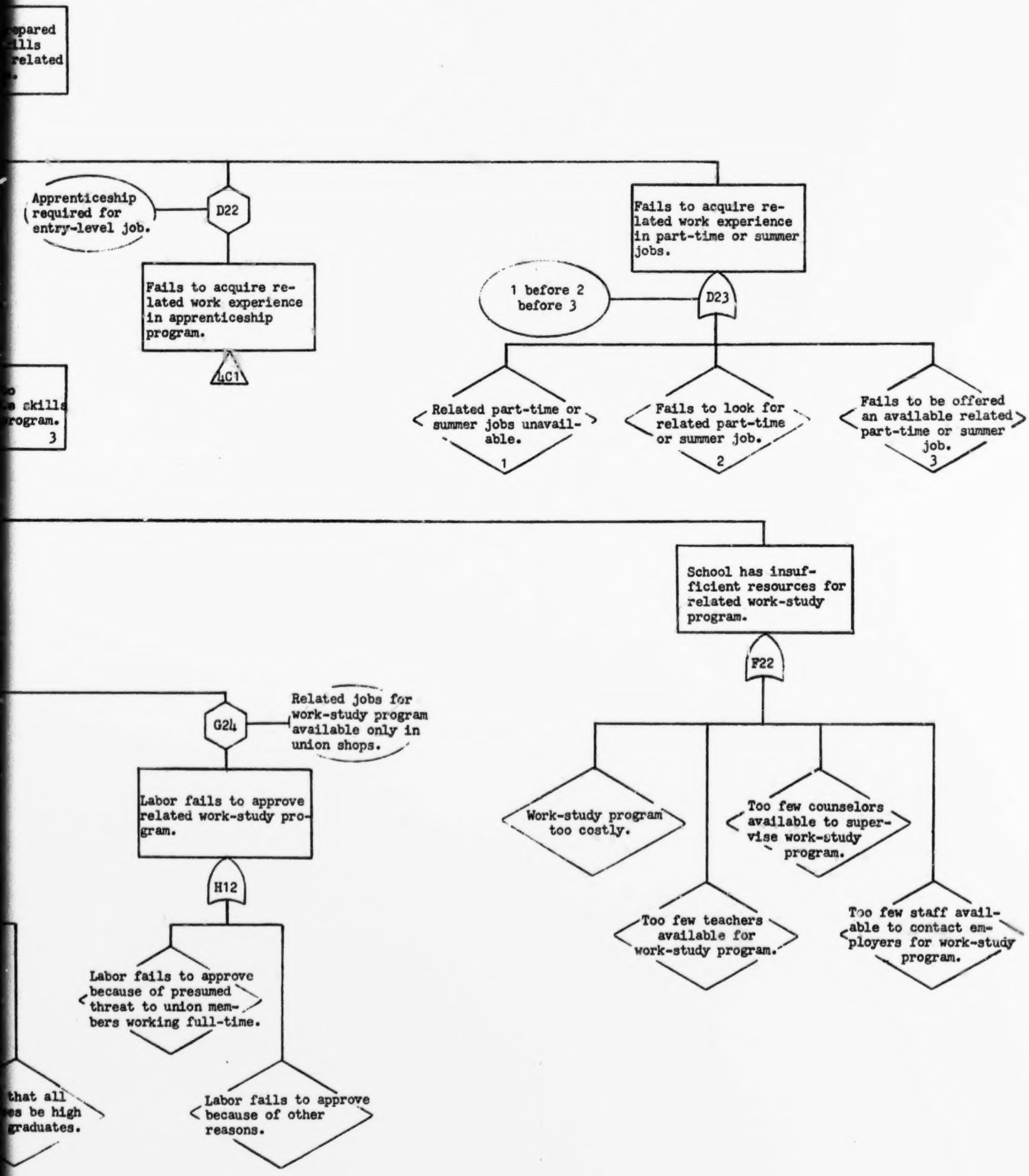


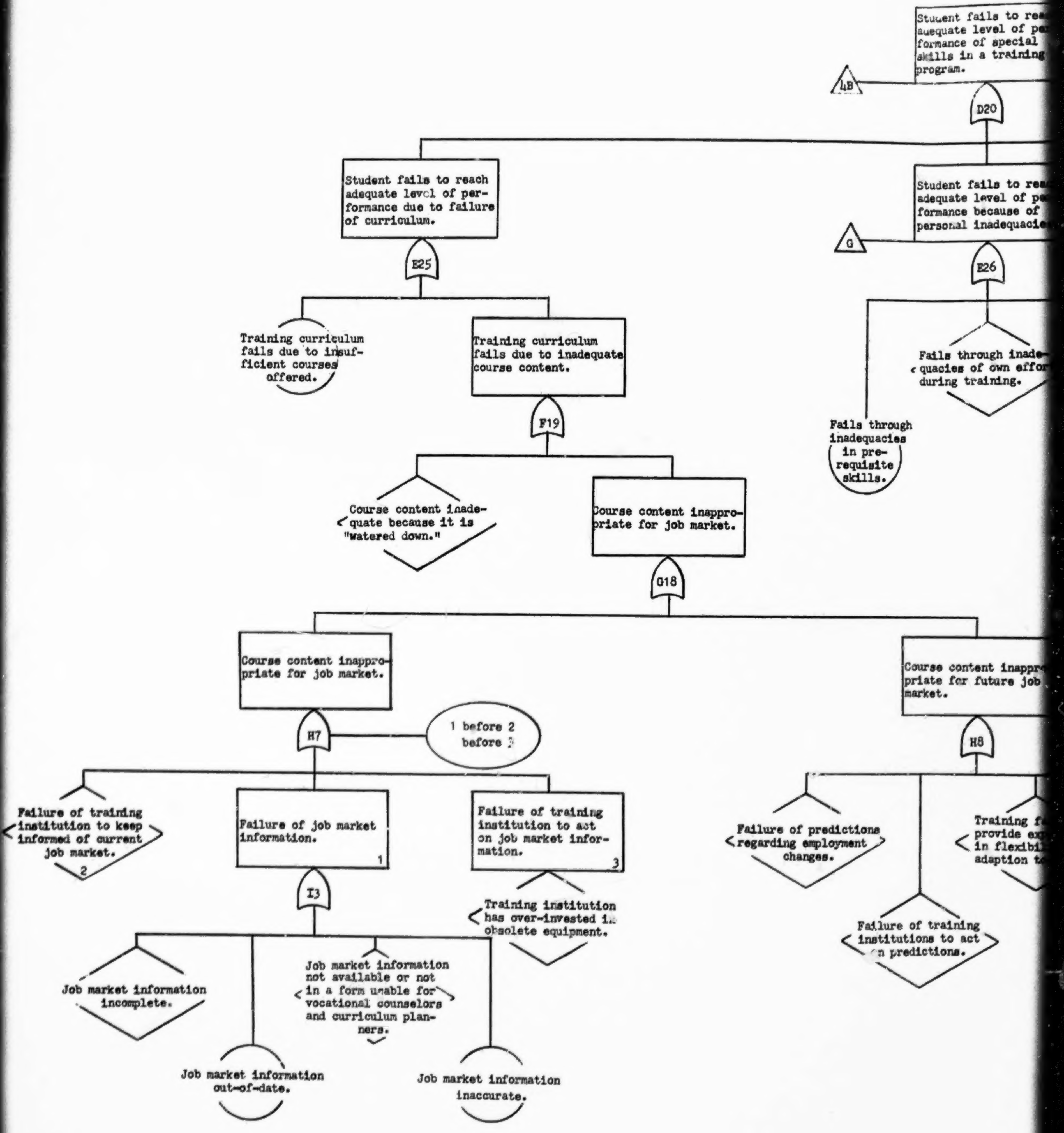
Failure because of insufficient awareness of own interests and working style.
3E
D17
Internal failure.
Counselor fails to give aptitude/interest tests.
Counselor fails to tell student the results of aptitude/interest tests.
E20
Fails to test because adequate tests unavailable.
Fails to test because of inadequate time.
Fails to test because does not trust the tests.

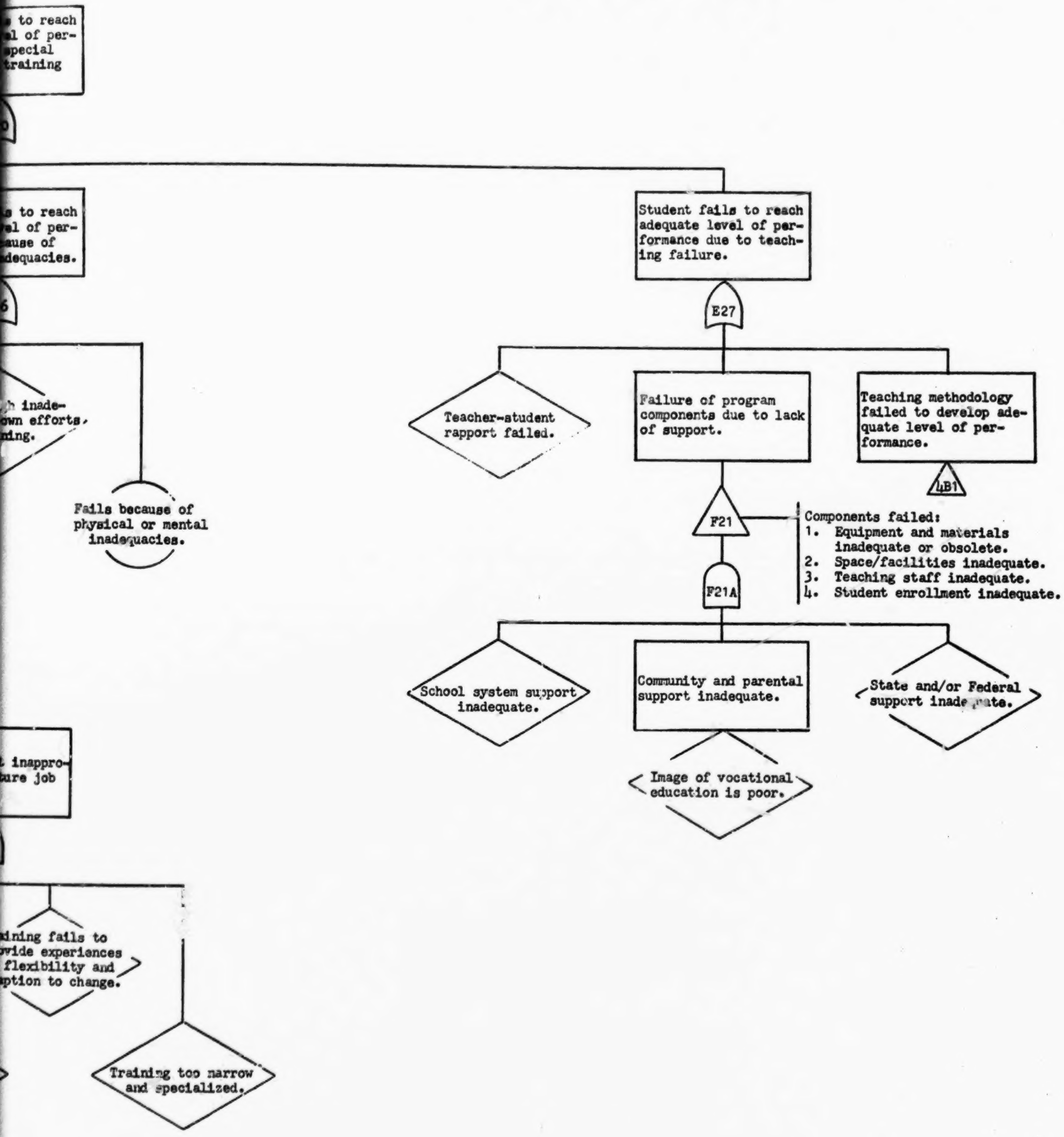

Fai
ly
ie
an
4
Inadequately prepared with special skills due to failure to acquire appropriate formal training.
Employer does not provide on-the-job training.
C10
Type
skil
1. S
a
2. A
e
t
C10A
Fails to acquire specialized training because no appropriate training is available to student.
D18
Student fails to reach an adequate level of performance of special skills in a training program.
4B
No appropriate specialized training available in private schools.
No appropriate specialized training is available in public schools.
No appropriate specialized training available in government funded programs.
E22
Appropriate specialized training is too costly.
Appropriate specialized training is too complex technologically.
School officials not convinced of need for appropriate specialized training.
Constraints of distance leading to failure to enter appropriate training program.
Appropriate training program is too far from student's home.
F16
No adequate transportation is available.
St
in
Student unable to move closer to work (e.g. restricted housing).

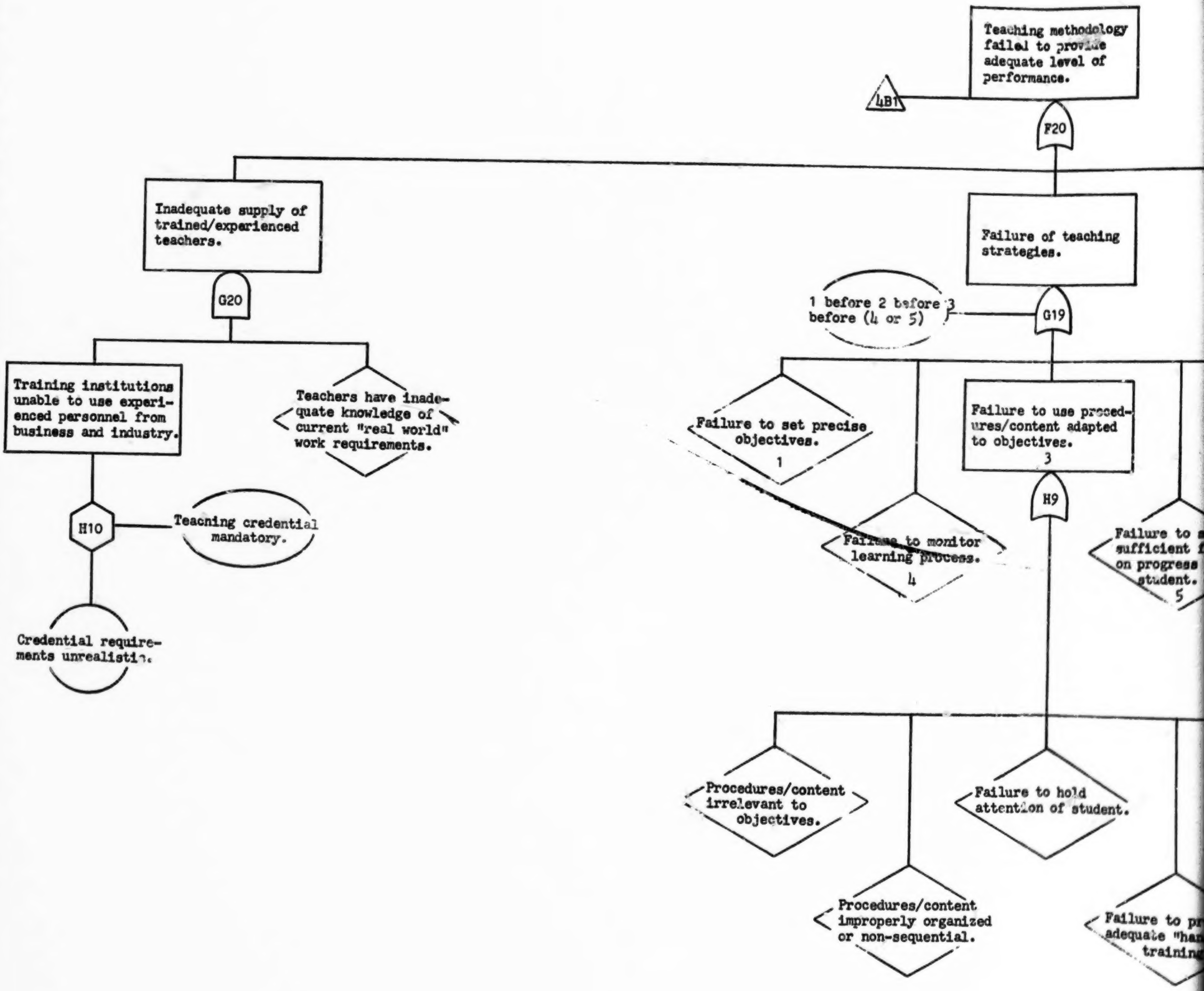

Failure to be adequately prepared with special skills needed for an entry-level job.
4
B4
y prepared
skills
re to
opriate
ing.
Inadequately prepared with special skills due to lack of related work experience.
4A
Types of specialized skills:
1. Specific vocational abilities.
2. Ancillary skills, e.g. of job application.
A
to reach
level of
of special
training
Student fails to enter an appropriate training program.
D19
Student fails to enter appropriate training program due to other constraints.
Student not aware of appropriate specialized training.
Student ineligible for appropriate specialized training.
E24
E23
Student fails to be motivated to enter appropriate training program.
Financial constraints leading to failure to enter appropriate training program.
Student ineligible due to physical or other handicap.
Student ineligible due to specific constraints of the program (e.g. income level too high for eligibility to MDTA).
F17
F18
Appropriate training program unavailable in public schools.
Student has unrealistic image of his own potential.
Student unable to afford private training program.
Student has poor image of vocational education.

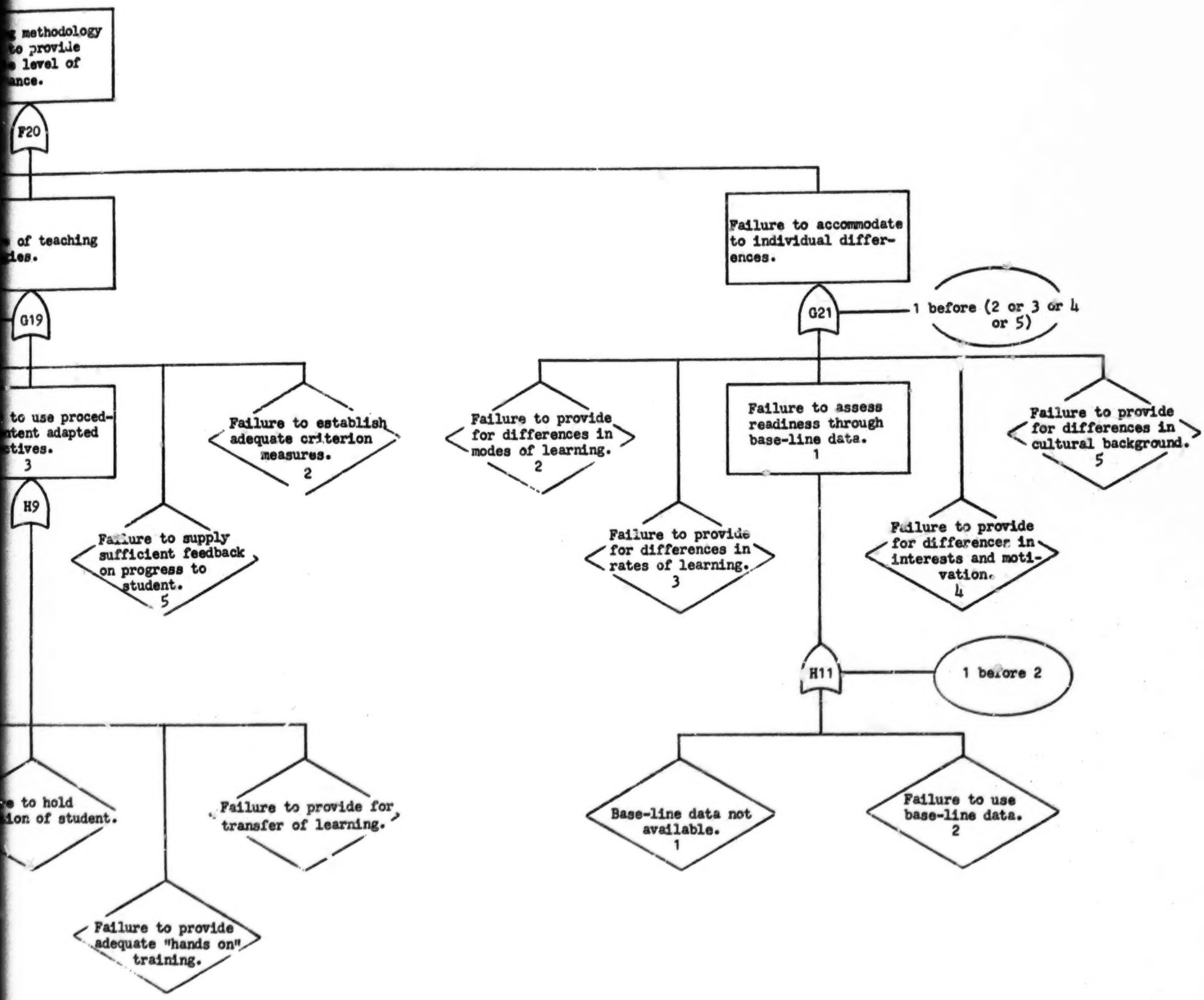

Inadequately prepared with special skills due to lack of related work experience.
4A
C11
Fails to acquire related work-experience in volunteer, non-paid jobs.
Fails to acquire related work experience in school-sponsored work-study program.
Apprenti
required
entry-le
1 before 2 before 3
D21
Student fails to enroll in related work-study program. 2
4C2
School fails to offer related work-study program. 1
E28
Student fails to acquire adequate skill in work-study program. 3
4C3
School unaware of benefits of related work-study program.
Industry fails to offer jobs for work-study program.
F23
Industry not convinced of benefits to it of work-study program.
G22
Insufficient number of appropriate jobs available for work-study program.
Industry corporate policies interfere with work-study program.
23
egular employees ave negative reaction o work-study program.
Too expensive for industry; (e.g. Workmen's Compensation & Minimum Wage Laws).
Too many legal restrictions.
Too much supervisory time required.
Too many problems created by part-time workers.
Misunderstanding of Child Labor Laws.
Regulations against part-time workers.
Policy that all employees be over 18 years of age.
Work permit problems for minors.
Policy that all employees be high school graduates.

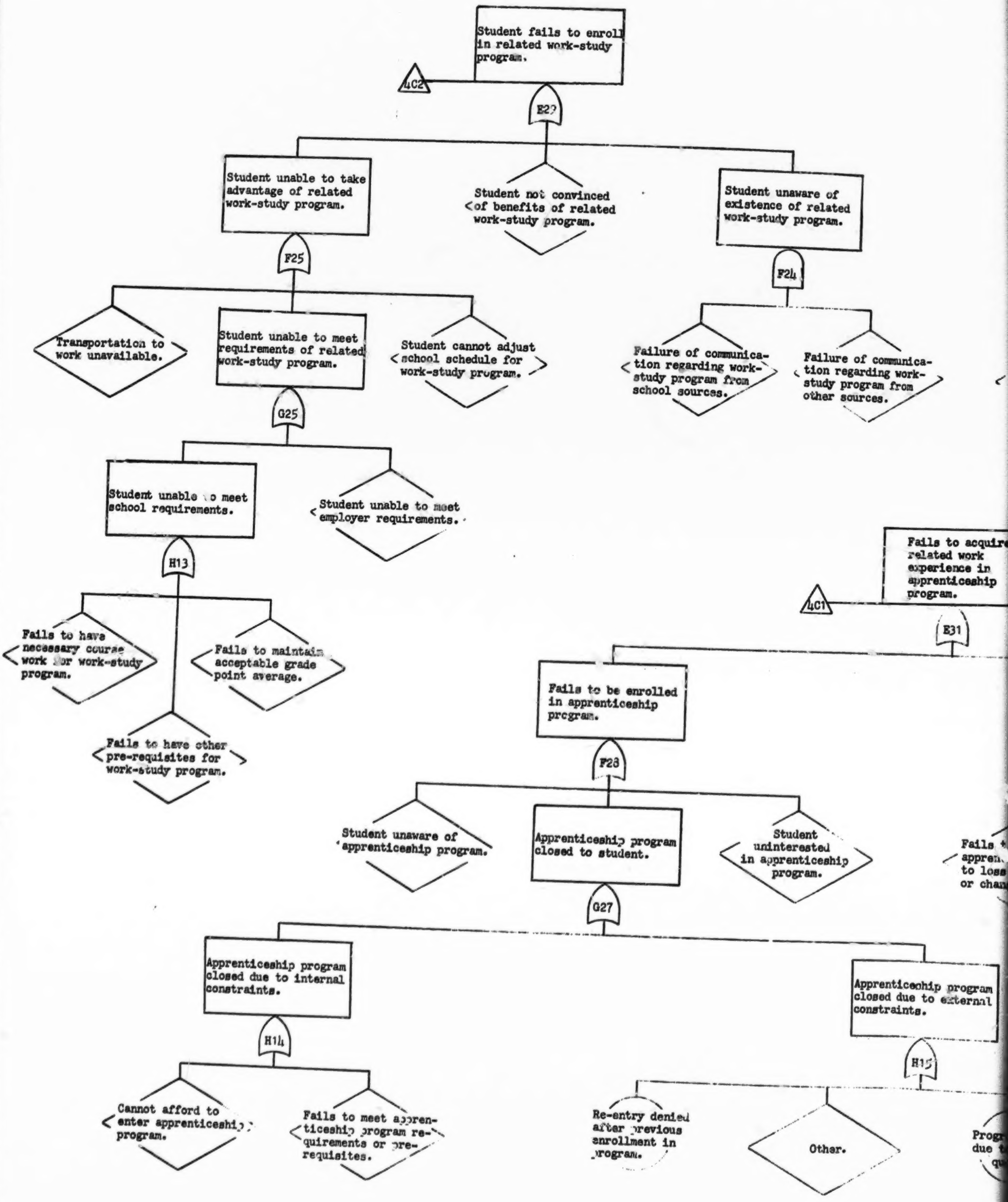

epared
ills
related
Apprenticeship required for entry-level job.
D22
Fails to acquire related work experience in apprenticeship program.
4C1
Fails to acquire related work experience in part-time or summer jobs.
1 before 2 before 3
D23
Related part-time or summer jobs unavailable.
1
Fails to look for related part-time or summer job.
2
Fails to be offered an available related part-time or summer job.
3
o
skills
rogram.
3
School has insufficient resources for related work-study program.
F22
Work-study program too costly.
Too few counselors available to supervise work-study program.
Too few teachers available for work-study program.
Too few staff available to contact employers for work-study program.
G24
Related jobs for work-study program available only in union shops.
Labor fails to approve related work-study program.
H12
Labor fails to approve because of presumed threat to union members working full-time.
Labor fails to approve because of other reasons.
that all
es be high
graduates.

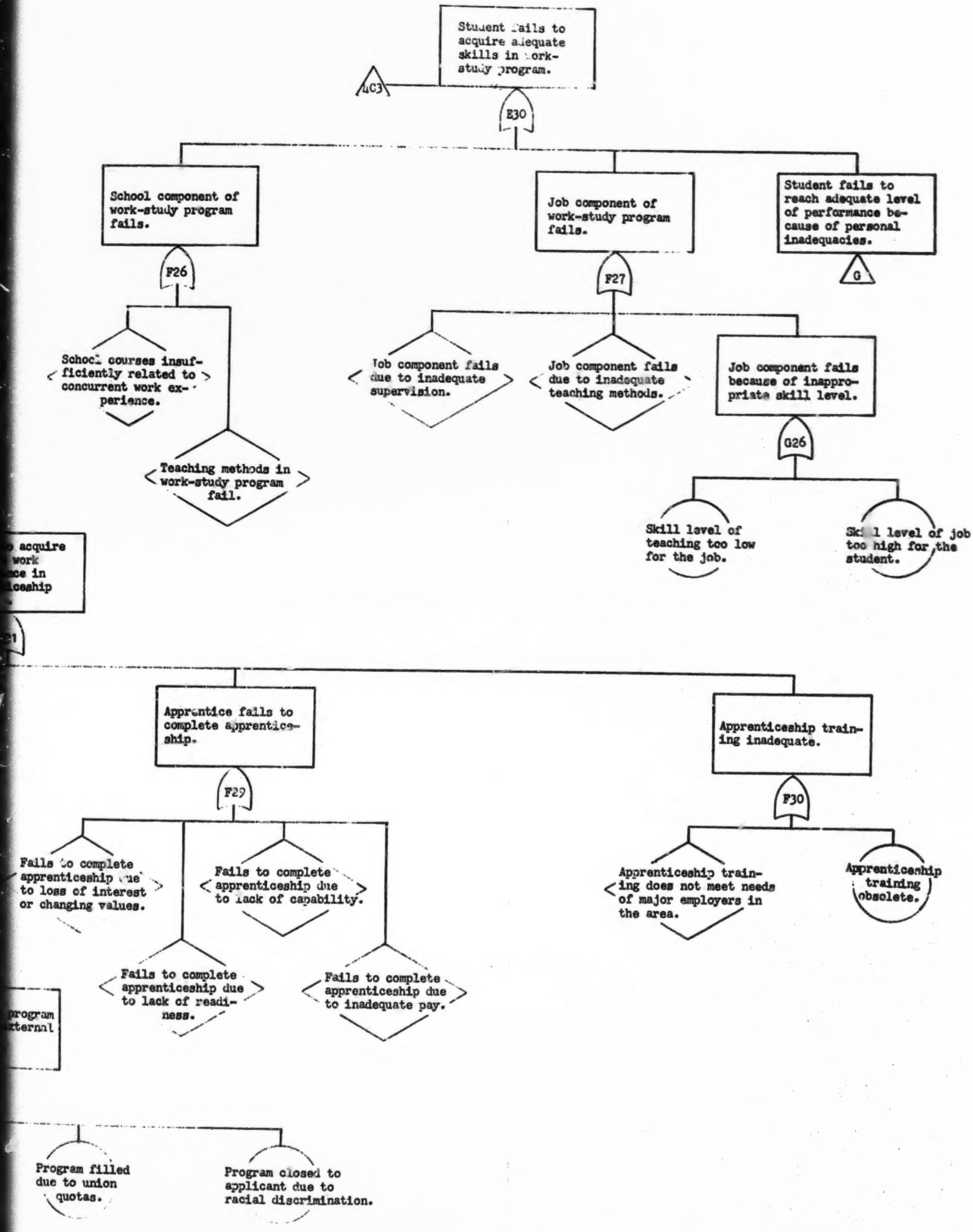

Student fails to rea
adequate level of pe
formance of special
skills in a training
program.
4B
D20
Student fails to reach
adequate level of per-
formance due to failure
of curriculum.
Student fails to rea
adequate level of pe
formance because of
personal inadequacie
G
E25
E26
Training curriculum
fails due to insuf-
ficient courses
offered.
Training curriculum
fails due to inadequate
course content.
Fails through inade-
quacies of own effor
during training.
Fails through
inadequacies
in pre-
requisite
skills.
F19
Course content inade-
quate because it is
"watered down."
Course content inappro-
priate for job market.
G18
Course content inappro-
priate for job market.
Course content inappr
priate for future job
market.
H7
1 before 2
before 3
H8
Failure of training
institution to keep
informed of current
job market.
2
Failure of job market
information.
1
Failure of training
institution to act
on job market infor-
mation.
3
Failure of predictions
regarding employment
changes.
Training f
provide ex
in flexibi
adaption t
I3
Training institution
has over-invested in
obsolete equipment.
Failure of training
institutions to act
on predictions.
Job market information
incomplete.
Job market information
not available or not
in a form usable for
vocational counselors
and curriculum plan-
ners.
Job market information
out-of-date.
Job market information
inaccurate.

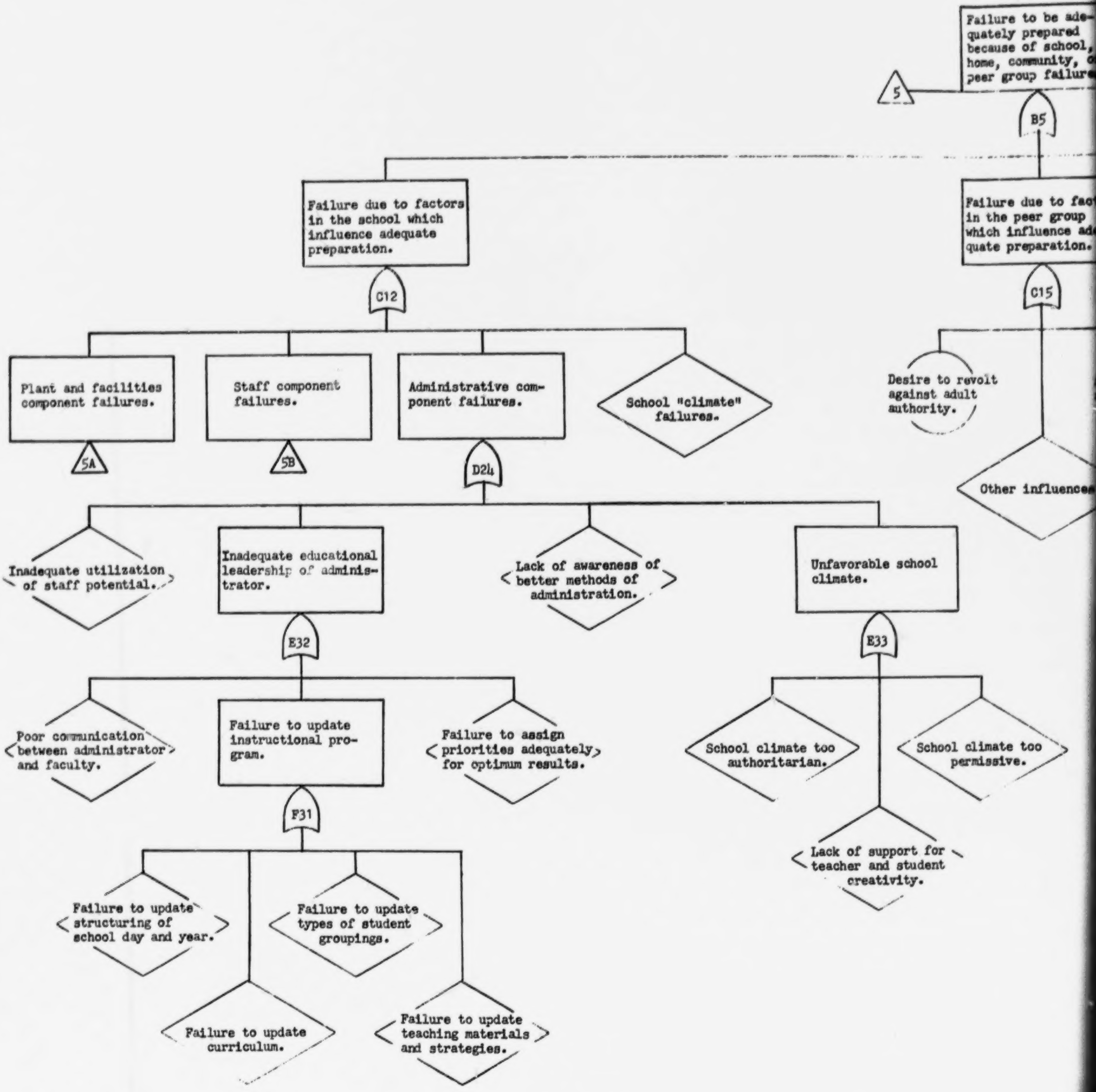

to reach
l of per-
pecial
training
to reach
l of per-
ause of
dequacies.
inade-
own efforts
ing.
Fails because of physical or mental inadequacies.
inappro-
ure job
ining fails to
vide experiences
flexibility and
ption to change.
Training too narrow and specialized.
Student fails to reach adequate level of performance due to teaching failure.
E27
Teacher-student rapport failed.
Failure of program components due to lack of support.
Teaching methodology failed to develop adequate level of performance.
4B1
F21
Components failed:
1. Equipment and materials inadequate or obsolete.
2. Space/facilities inadequate.
3. Teaching staff inadequate.
4. Student enrollment inadequate.
F21A
School system support inadequate.
Community and parental support inadequate.
State and/or Federal support inadequate.
Image of vocational education is poor.

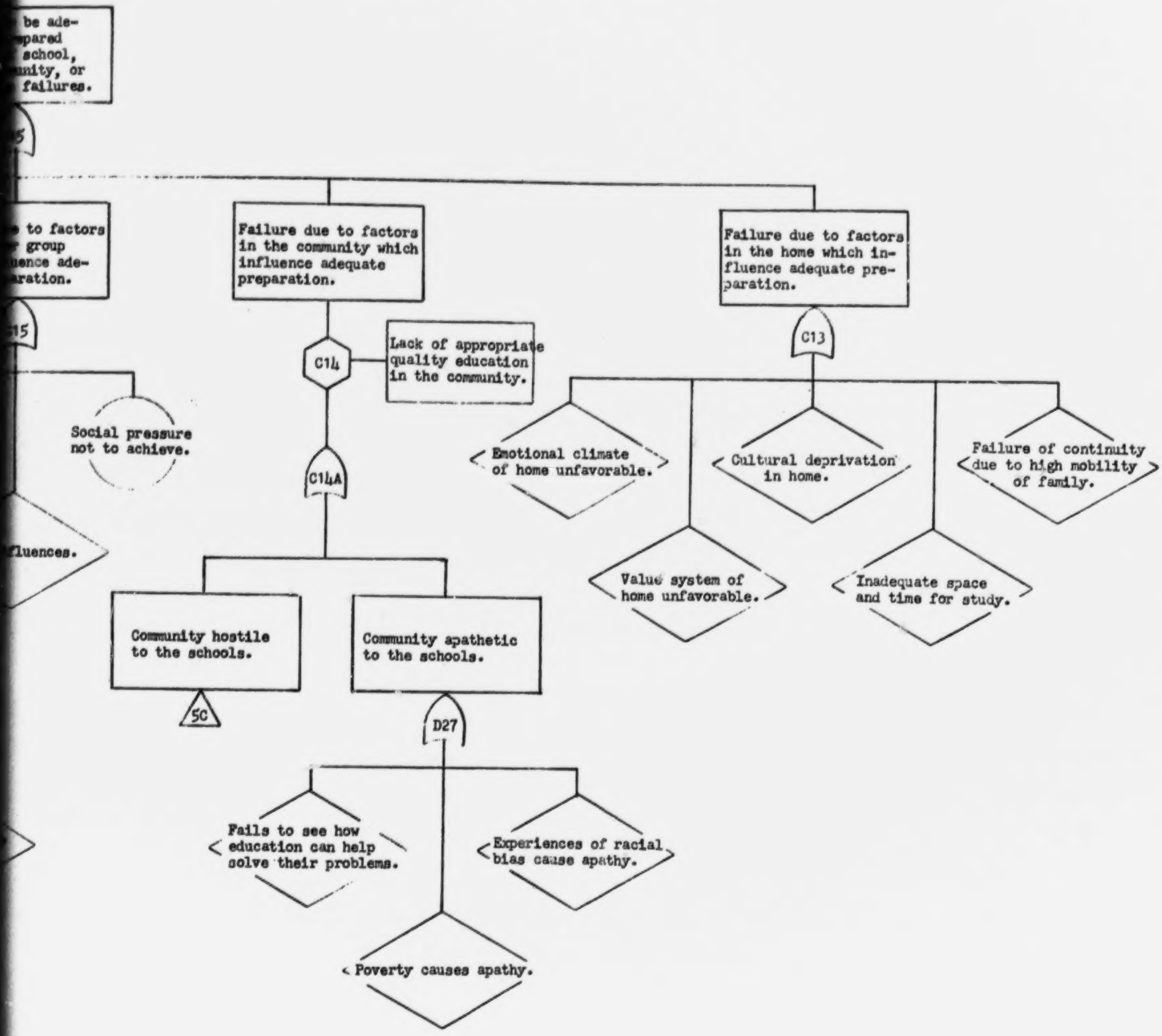

Teaching methodology failed to provide adequate level of performance.
4B1
F20
Inadequate supply of trained/experienced teachers.
G20
Training institutions unable to use experienced personnel from business and industry.
Teachers have inadequate knowledge of current "real world" work requirements.
H10
Teaching credential mandatory.
Credential requirements unrealistic.
Failure of teaching strategies.
1 before 2 before 3 before (4 or 5)
G19
Failure to set precise objectives.
1
Failure to use procedures/content adapted to objectives.
3
Failure to monitor learning process.
4
Failure to s
sufficient f
on progress
student.
5
H9
Procedures/content irrelevant to objectives.
Failure to hold attention of student.
Procedures/content improperly organized or non-sequential.
Failure to pr
adequate "han
training

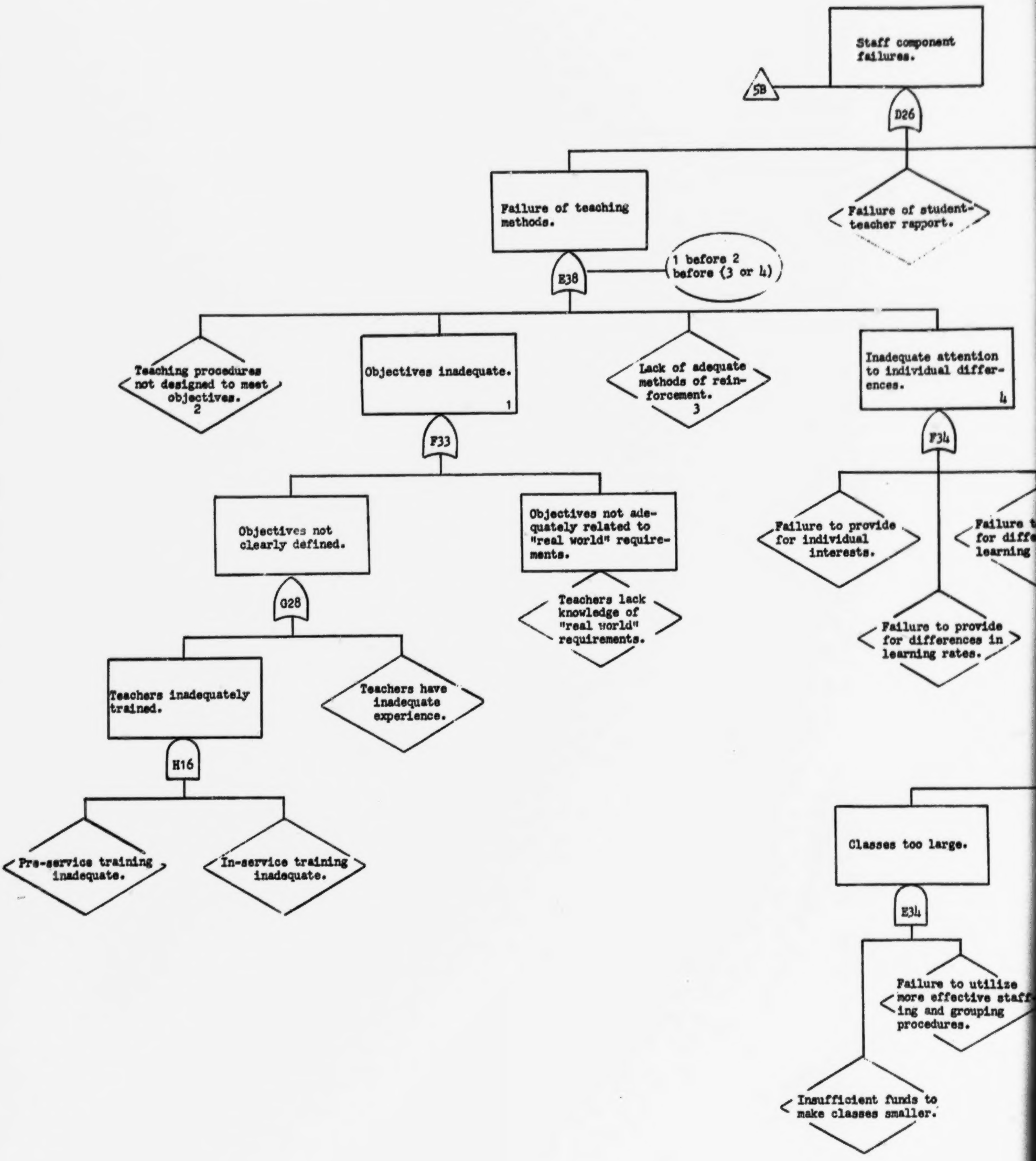

g methodology to provide e level of ance.
F20
of teaching ies.
G19
to use proced- ntent adapted ctives. 3
H9
Failure to establish adequate criterion measures. 2
Failure to supply sufficient feedback on progress to student. 5
e to hold ion of student.
Failure to provide for transfer of learning.
Failure to provide adequate "hands on" training.
Failure to accommodate to individual differ- ences.
G21
1 before (2 or 3 or 4 or 5)
Failure to provide for differences in modes of learning. 2
Failure to assess readiness through base-line data. 1
Failure to provide for differences in cultural background. 5
Failure to provide for differences in rates of learning. 3
Failure to provide for differences in interests and moti- vation. 4
H11
1 before 2
Base-line data not available. 1
Failure to use base-line data. 2

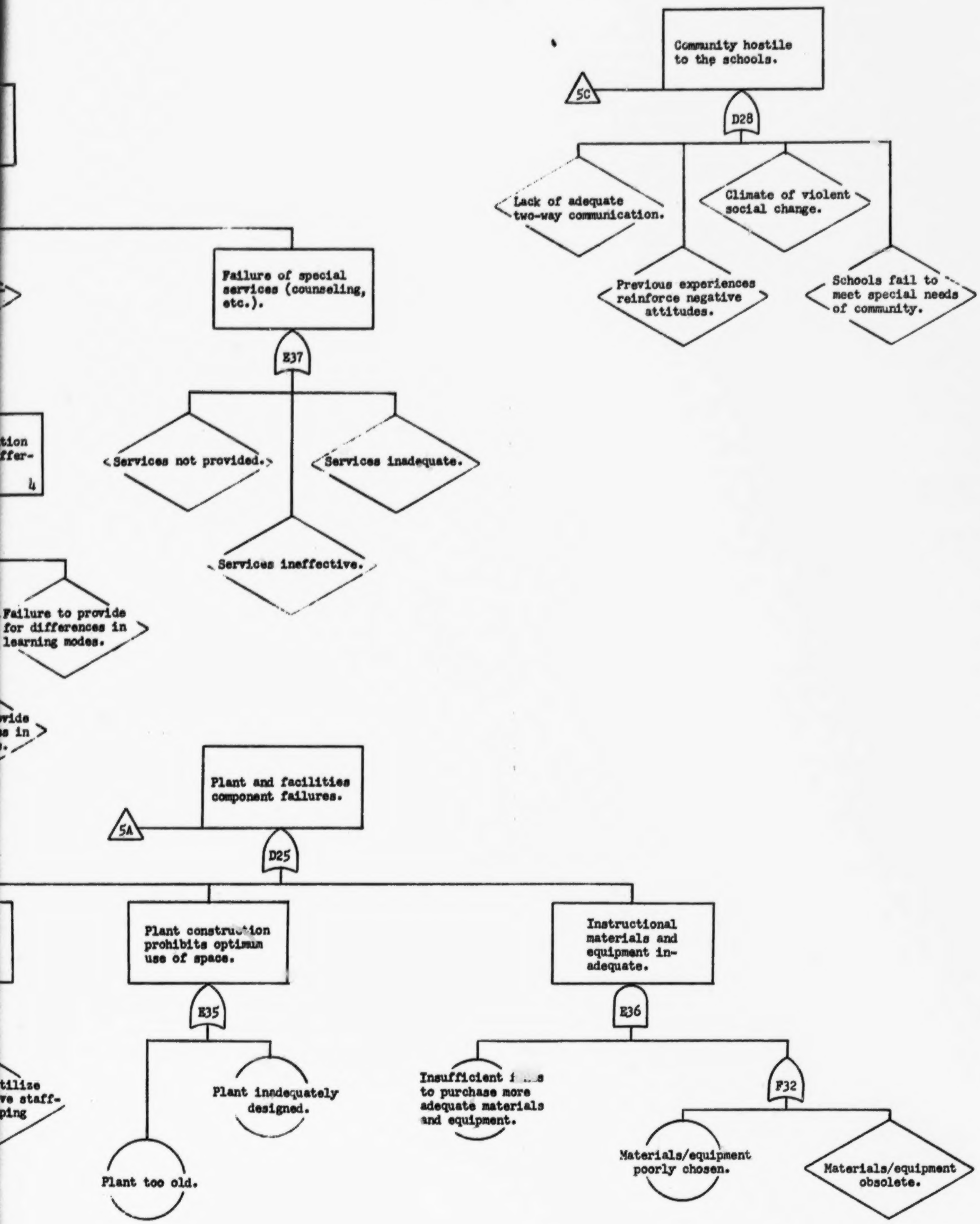

Student fails to enroll in related work-study program.
4C2
E22
Student unable to take advantage of related work-study program.
Student not convinced of benefits of related work-study program.
Student unaware of existence of related work-study program.
F25
F24
Transportation to work unavailable.
Student unable to meet requirements of related work-study program.
Student cannot adjust school schedule for work-study program.
Failure of communication regarding work-study program from school sources.
Failure of communication regarding work-study program from other sources.
G25
Student unable to meet school requirements.
Student unable to meet employer requirements.
H13
Fails to have necessary course work for work-study program.
Fails to maintain acceptable grade point average.
Fails to have other pre-requisites for work-study program.
Fails to acquir
related work
experience in
apprenticeship
program.
4C1
E31
Fails to be enrolled in apprenticeship program.
F26
Student unaware of apprenticeship program.
Apprenticeship program closed to student.
Student uninterested in apprenticeship program.
Fails
appren
to loss
or chan
G27
Apprenticeship program closed due to internal constraints.
Apprenticeship program closed due to external constraints.
H14
H15
Cannot afford to enter apprenticeship program.
Fails to meet apprenticeship program requirements or pre-requisites.
Re-entry denied after previous enrollment in program.
Other.
Progr
due t
qu

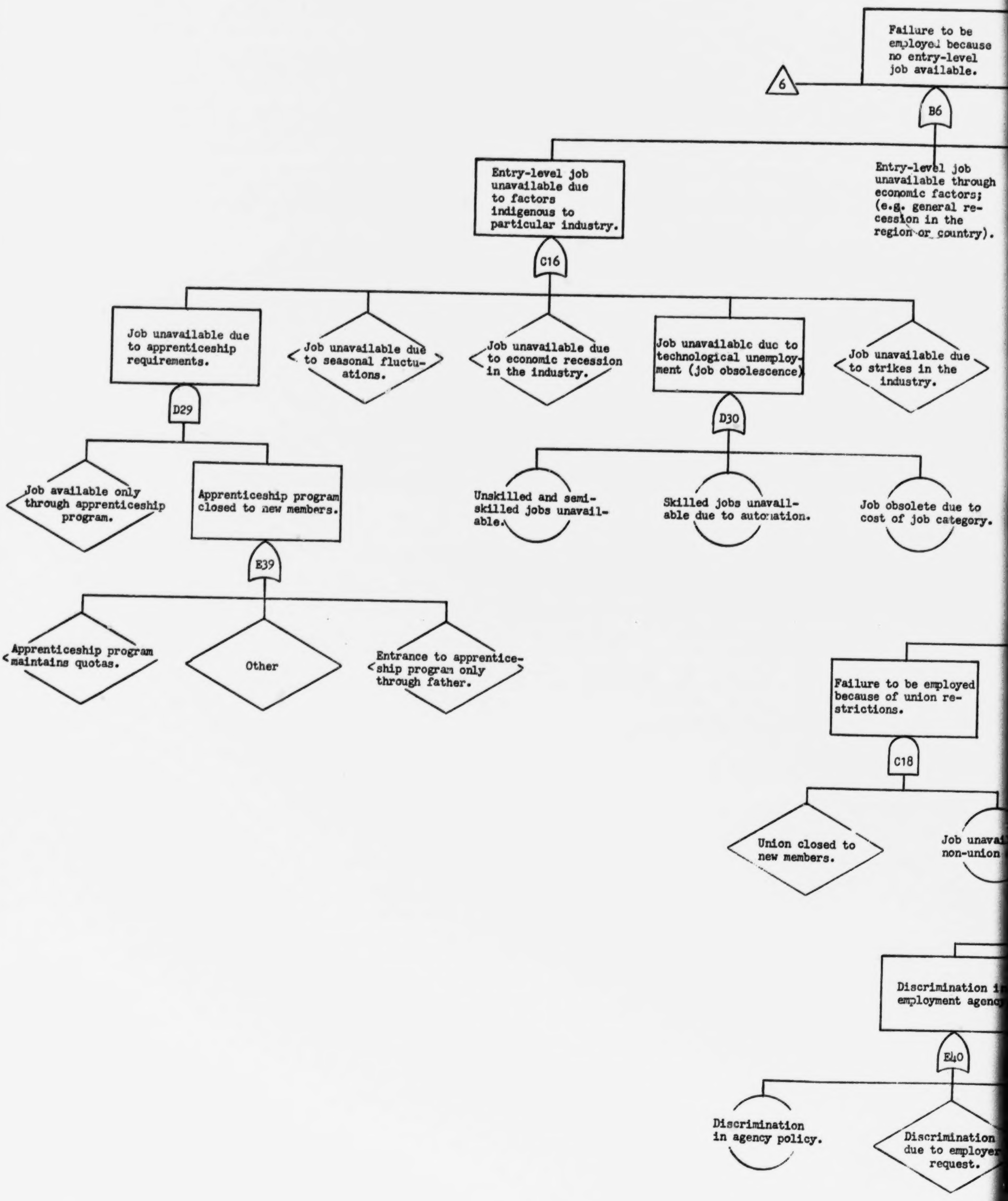

Student fails to acquire adequate skills in work-study program.
4C3
E30
School component of work-study program fails.
Job component of work-study program fails.
Student fails to reach adequate level of performance because of personal inadequacies.
G
F26
F27
School courses insufficiently related to concurrent work experience.
Teaching methods in work-study program fail.
Job component fails due to inadequate supervision.
Job component fails due to inadequate teaching methods.
Job component fails because of inappropriate skill level.
G26
Skill level of teaching too low for the job.
Skill level of job too high for the student.
o acquire
work
ce in
iceship
21
Apprentice fails to complete apprenticeship.
Apprenticeship training inadequate.
F29
F30
Fails to complete apprenticeship due to loss of interest or changing values.
Fails to complete apprenticeship due to lack of capability.
Fails to complete apprenticeship due to lack of readiness.
Fails to complete apprenticeship due to inadequate pay.
Apprenticeship training does not meet needs of major employers in the area.
Apprenticeship training obsolete.
program
xternal
Program filled due to union quotas.
Program closed to applicant due to racial discrimination.

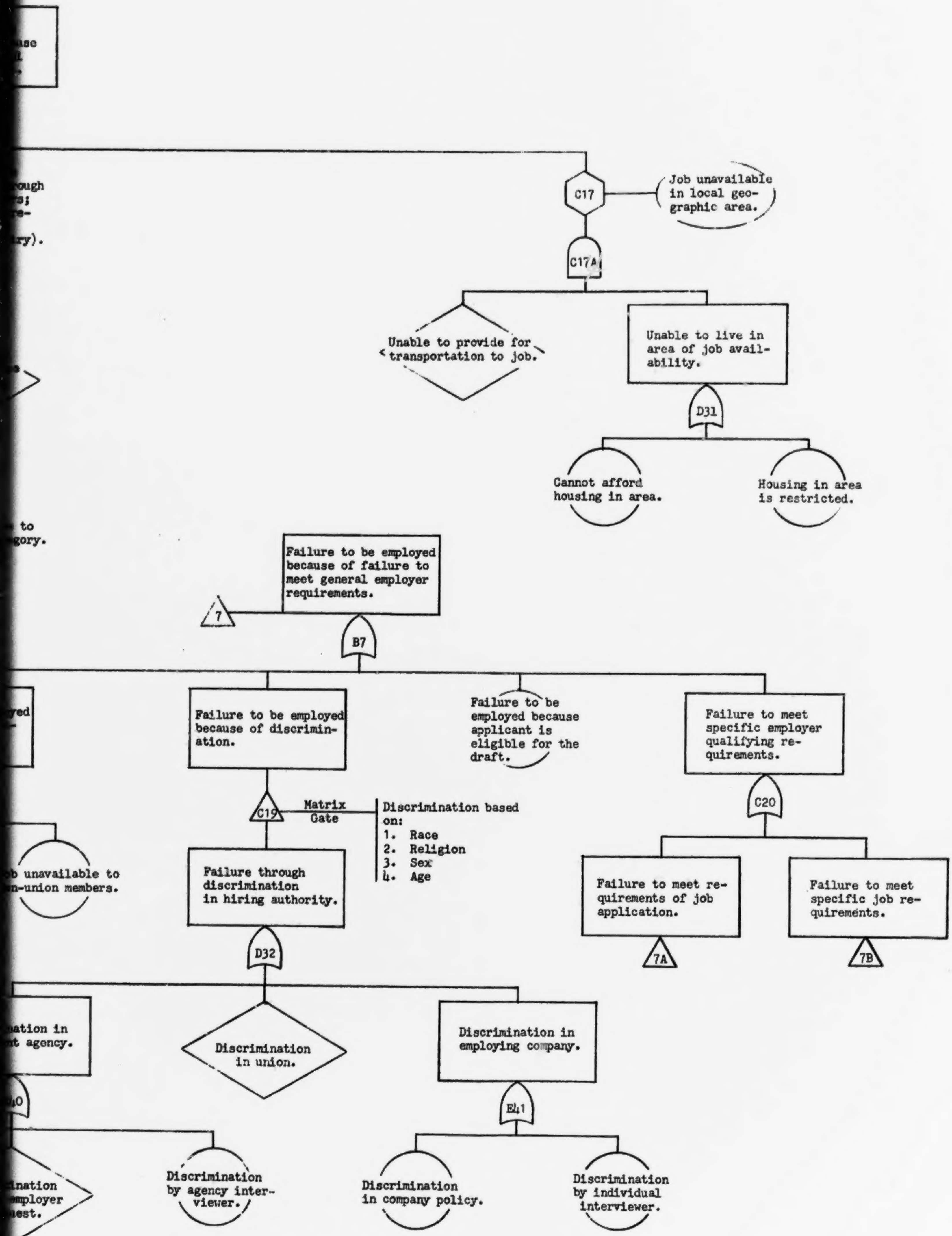

Failure to be ade-
quately prepared
because of school,
home, community, o
peer group failure
5
B5
Failure due to factors
in the school which
influence adequate
preparation.
C12
Failure due to fac
in the peer group
which influence ad
quate preparation.
C15
Plant and facilities
component failures.
5A
Staff component
failures.
5B
Administrative com-
ponent failures.
D24
School "climate"
failures.
Desire to revolt
against adult
authority.
Other influences
Inadequate utilization
of staff potential.
Inadequate educational
leadership of adminis-
trator.
E32
Lack of awareness of
better methods of
administration.
Unfavorable school
climate.
E33
Poor communication
between administrator
and faculty.
Failure to update
instructional pro-
gram.
F31
Failure to assign
priorities adequately
for optimum results.
School climate too
authoritarian.
School climate too
permissive.
Lack of support for
teacher and student
creativity.
Failure to update
structuring of
school day and year.
Failure to update
types of student
groupings.
Failure to update
curriculum.
Failure to update
teaching materials
and strategies.

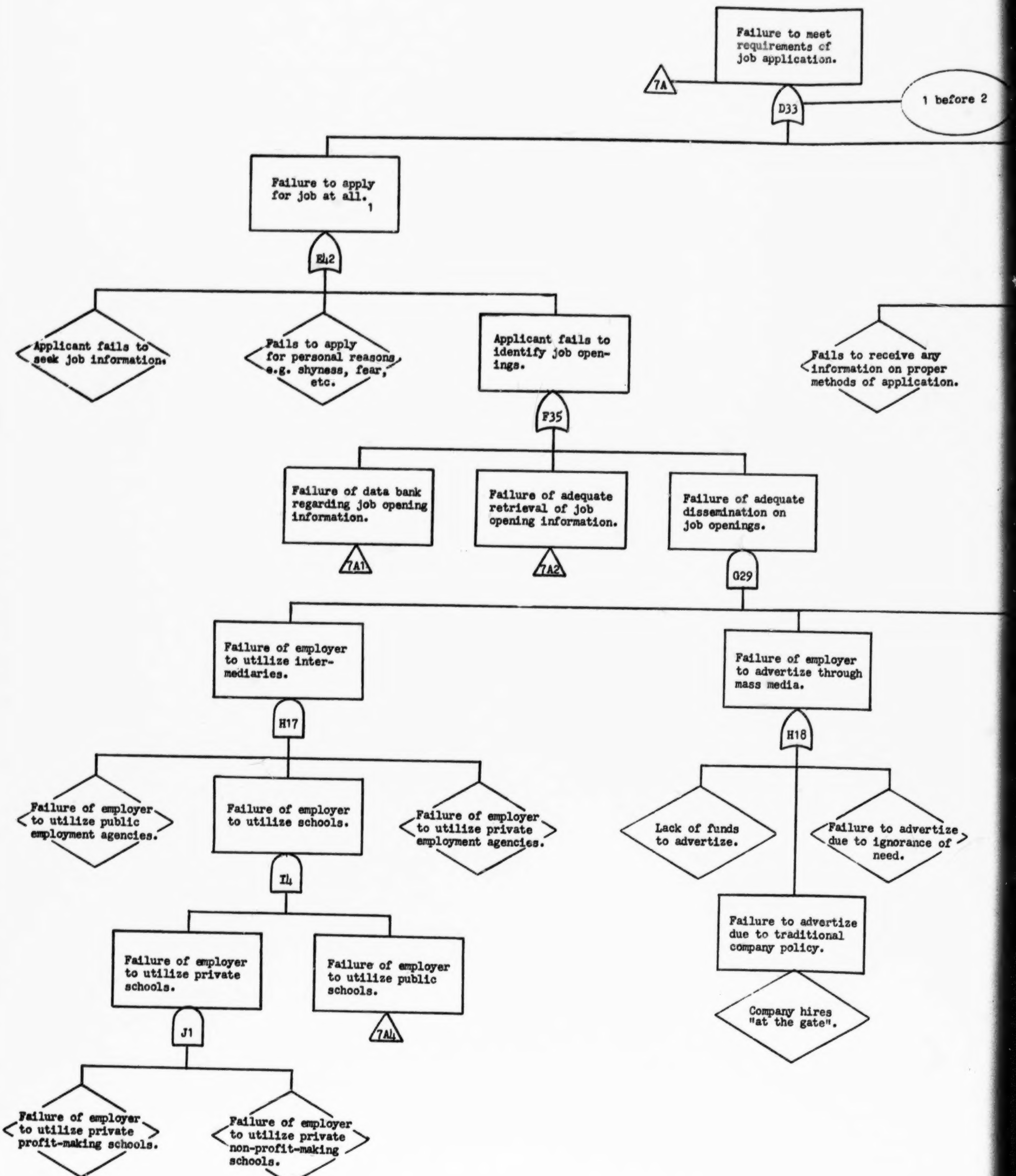

be ade- pared school, unity, or failures.
to factors group uence ade- aration.
15
Social pressure not to achieve.
fluences.
Failure due to factors in the community which influence adequate preparation.
C14
Lack of appropriate quality education in the community.
C14A
Community hostile to the schools.
5C
Community apathetic to the schools.
D27
Fails to see how education can help solve their problems.
Experiences of racial bias cause apathy.
Poverty causes apathy.
Failure due to factors in the home which influence adequate preparation.
C13
Emotional climate of home unfavorable.
Value system of home unfavorable.
Cultural deprivation in home.
Inadequate space and time for study.
Failure of continuity due to high mobility of family.

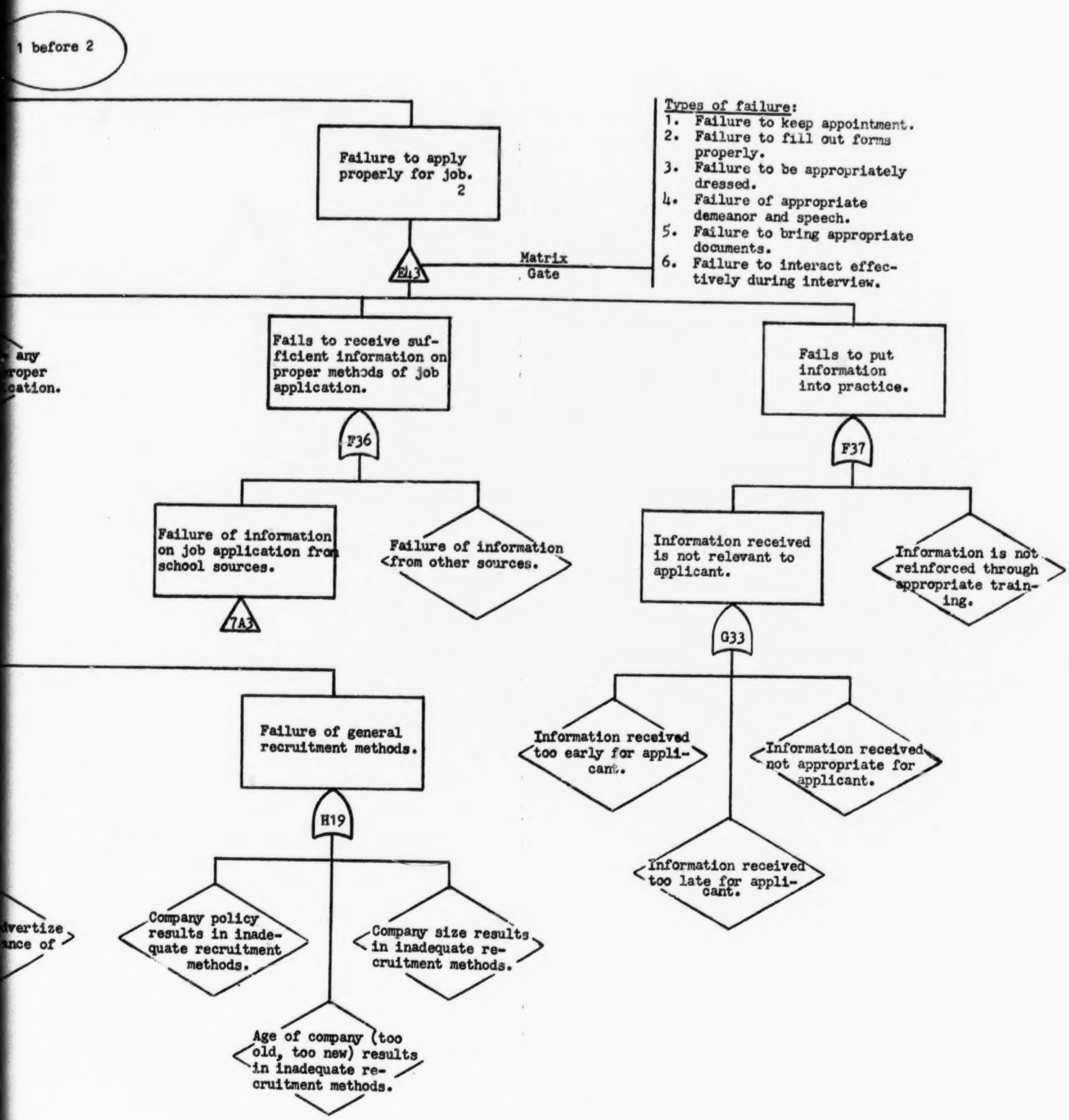

Staff component failures.
5B
D26
Failure of teaching methods.
Failure of student-teacher rapport.
E38
1 before 2 before (3 or 4)
Teaching procedures not designed to meet objectives. 2
Objectives inadequate. 1
Lack of adequate methods of reinforcement. 3
Inadequate attention to individual differences. 4
F33
F34
Objectives not clearly defined.
Objectives not adequately related to "real world" requirements.
Teachers lack knowledge of "real world" requirements.
Failure to provide for individual interests.
Failure t for diffe learning
Failure to provide for differences in learning rates.
G28
Teachers inadequately trained.
Teachers have inadequate experience.
H16
Pre-service training inadequate.
In-service training inadequate.
Classes too large.
E34
Failure to utilize more effective staff-ing and grouping procedures.
Insufficient funds to make classes smaller.


Community hostile to the schools.
5C
D28
Lack of adequate two-way communication.
Climate of violent social change.
Previous experiences reinforce negative attitudes.
Schools fail to meet special needs of community.
Failure of special services (counseling, etc.).
E37
Services not provided.
Services inadequate.
Services ineffective.
ation
iffer-
4
Failure to provide for differences in learning modes.
ovide
es in
s.
Plant and facilities component failures.
5A
D25
Plant construction prohibits optimum use of space.
E35
Plant too old.
Plant inadequately designed.
Instructional materials and equipment inadequate.
E36
Insufficient funds to purchase more adequate materials and equipment.
F32
Materials/equipment poorly chosen.
Materials/equipment obsolete.
utilize
ive staff-
uping

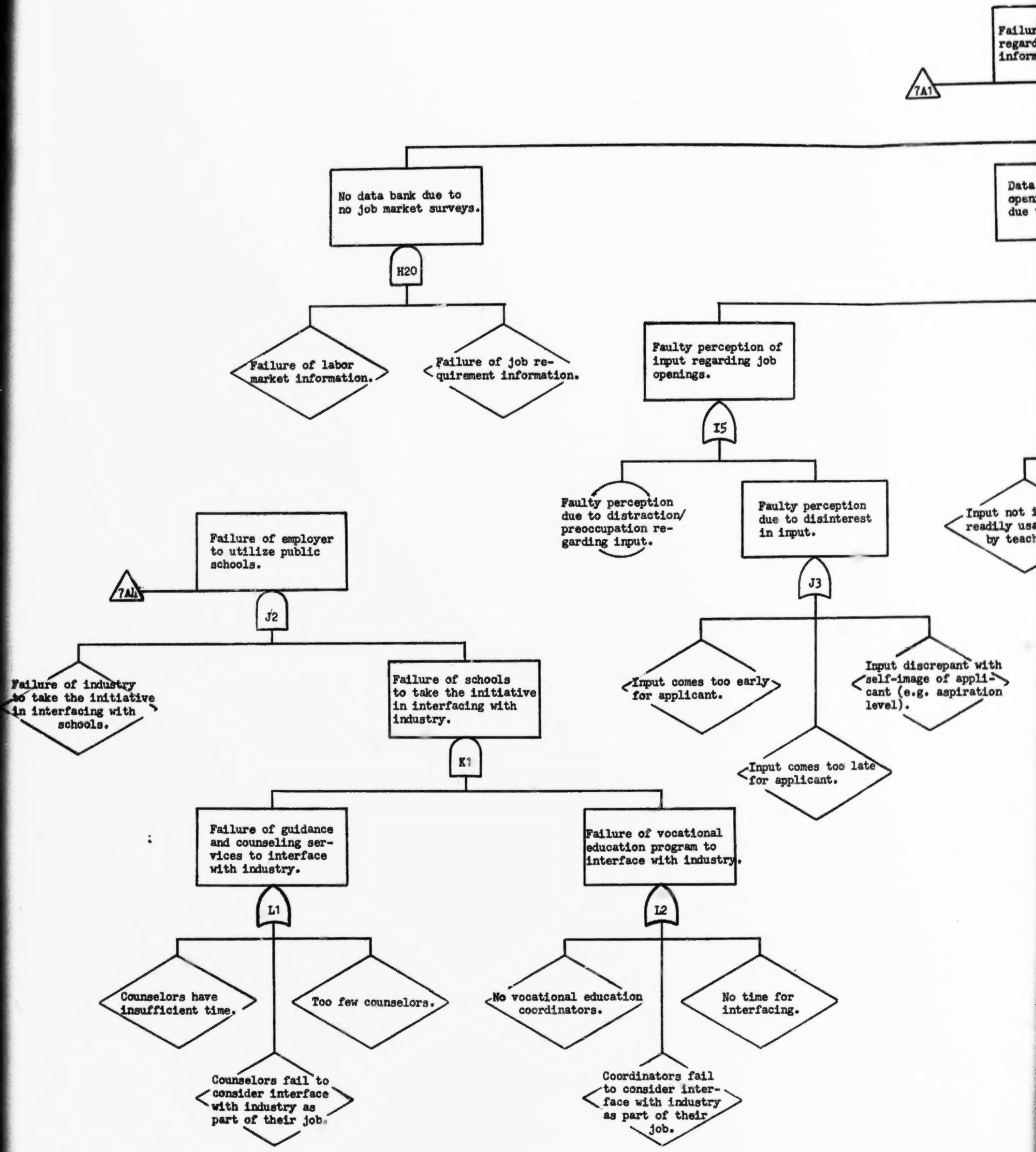

Failure to be employed because no entry-level job available.
6
B6
Entry-level job unavailable due to factors indigenous to particular industry.
Entry-level job unavailable through economic factors; (e.g. general recession in the region or country).
C16
Job unavailable due to apprenticeship requirements.
Job unavailable due to seasonal fluctuations.
Job unavailable due to economic recession in the industry.
Job unavailable due to technological unemployment (job obsolescence)
Job unavailable due to strikes in the industry.
D29
D30
Job available only through apprenticeship program.
Apprenticeship program closed to new members.
Unskilled and semi-skilled jobs unavailable.
Skilled jobs unavailable due to automation.
Job obsolete due to cost of job category.
E39
Apprenticeship program maintains quotas.
Other
Entrance to apprenticeship program only through father.
Failure to be employed because of union restrictions.
C18
Union closed to new members.
Job unavai
non-union
Discrimination i
employment agenc
E40
Discrimination in agency policy.
Discrimination due to employer request.

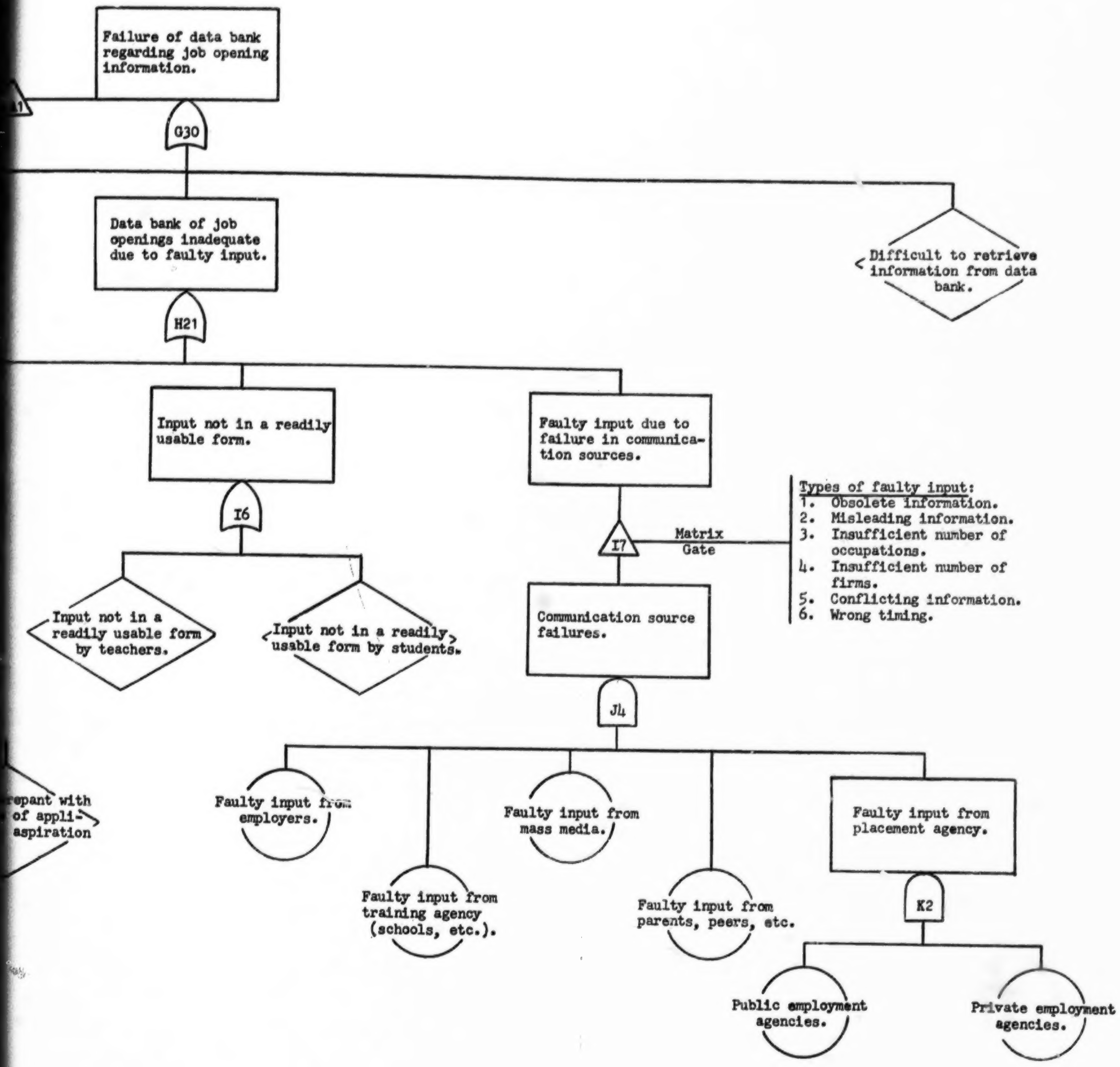

ause
l
C17
Job unavailable in local geographic area.
C17A
Unable to provide for transportation to job.
Unable to live in area of job availability.
D31
Cannot afford housing in area.
Housing in area is restricted.
rough
rs;
re-
ry).
to
gory.
Failure to be employed because of failure to meet general employer requirements.
7
B7
yed
Failure to be employed because of discrimination.
Failure to be employed because applicant is eligible for the draft.
Failure to meet specific employer qualifying requirements.
C19
Matrix Gate
Discrimination based on:
1. Race
2. Religion
3. Sex
4. Age
C20
b unavailable to
n-union members.
Failure through discrimination in hiring authority.
Failure to meet requirements of job application.
Failure to meet specific job requirements.
7A
7B
D32
ation in
t agency.
Discrimination in union.
Discrimination in employing company.
40
E41
ination
mployer
est.
Discrimination by agency interviewer.
Discrimination in company policy.
Discrimination by individual interviewer.

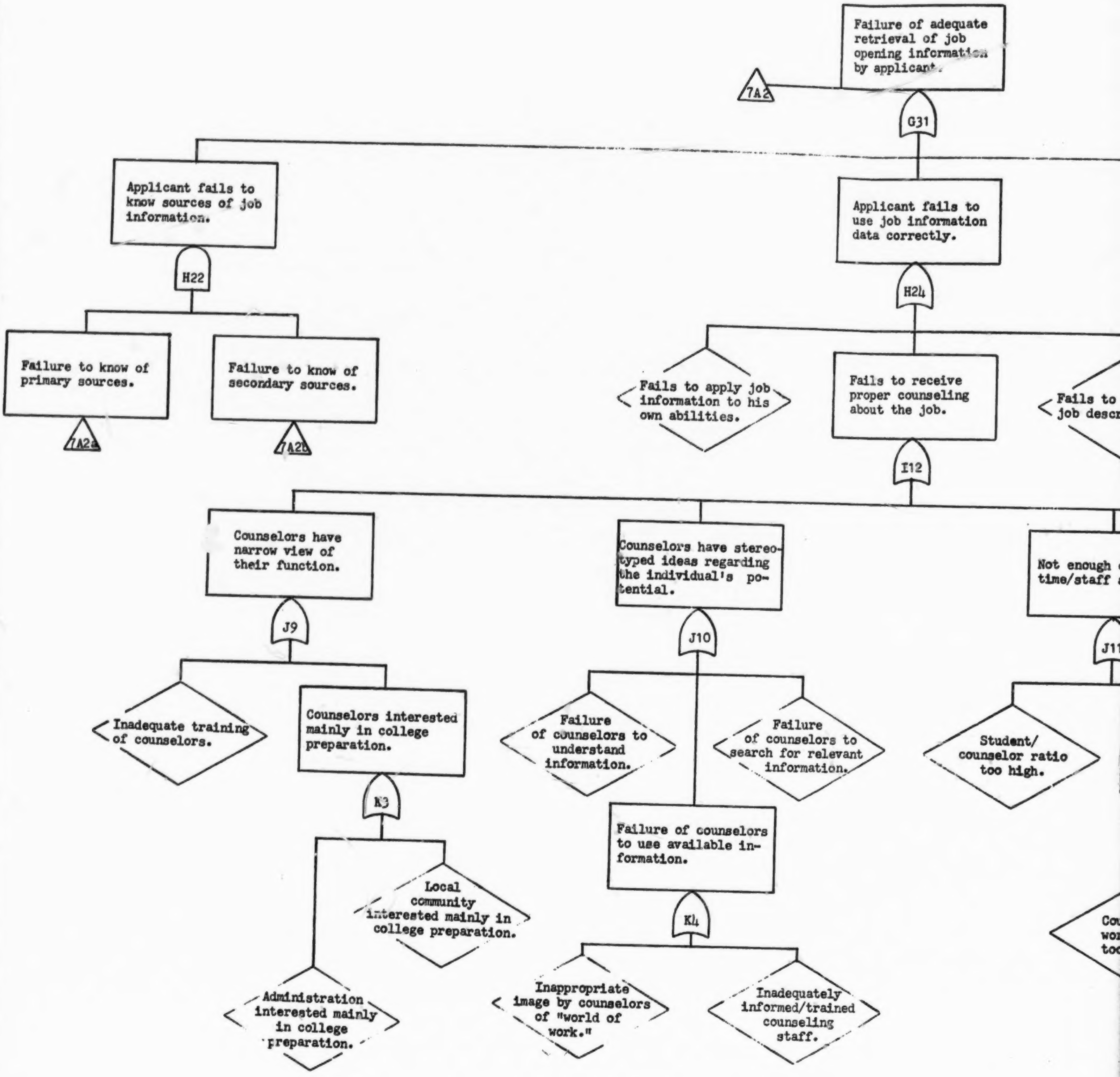

Failure to meet requirements of job application.
7A
D33
1 before 2
Failure to apply for job at all. 1
E42
Applicant fails to seek job information.
Fails to apply for personal reasons, e.g. shyness, fear, etc.
Applicant fails to identify job openings.
F35
Failure of data bank regarding job opening information.
7A1
Failure of adequate retrieval of job opening information.
7A2
Failure of adequate dissemination on job openings.
G29
Failure of employer to utilize intermediaries.
H17
Failure of employer to utilize public employment agencies.
Failure of employer to utilize schools.
I4
Failure of employer to utilize private employment agencies.
Failure of employer to utilize private schools.
J1
Failure of employer to utilize private profit-making schools.
Failure of employer to utilize private non-profit-making schools.
Failure of employer to utilize public schools.
7A4
Failure of employer to advertize through mass media.
H18
Lack of funds to advertize.
Failure to advertize due to ignorance of need.
Failure to advertize due to traditional company policy.
Company hires "at the gate".
Fails to receive any information on proper methods of application.

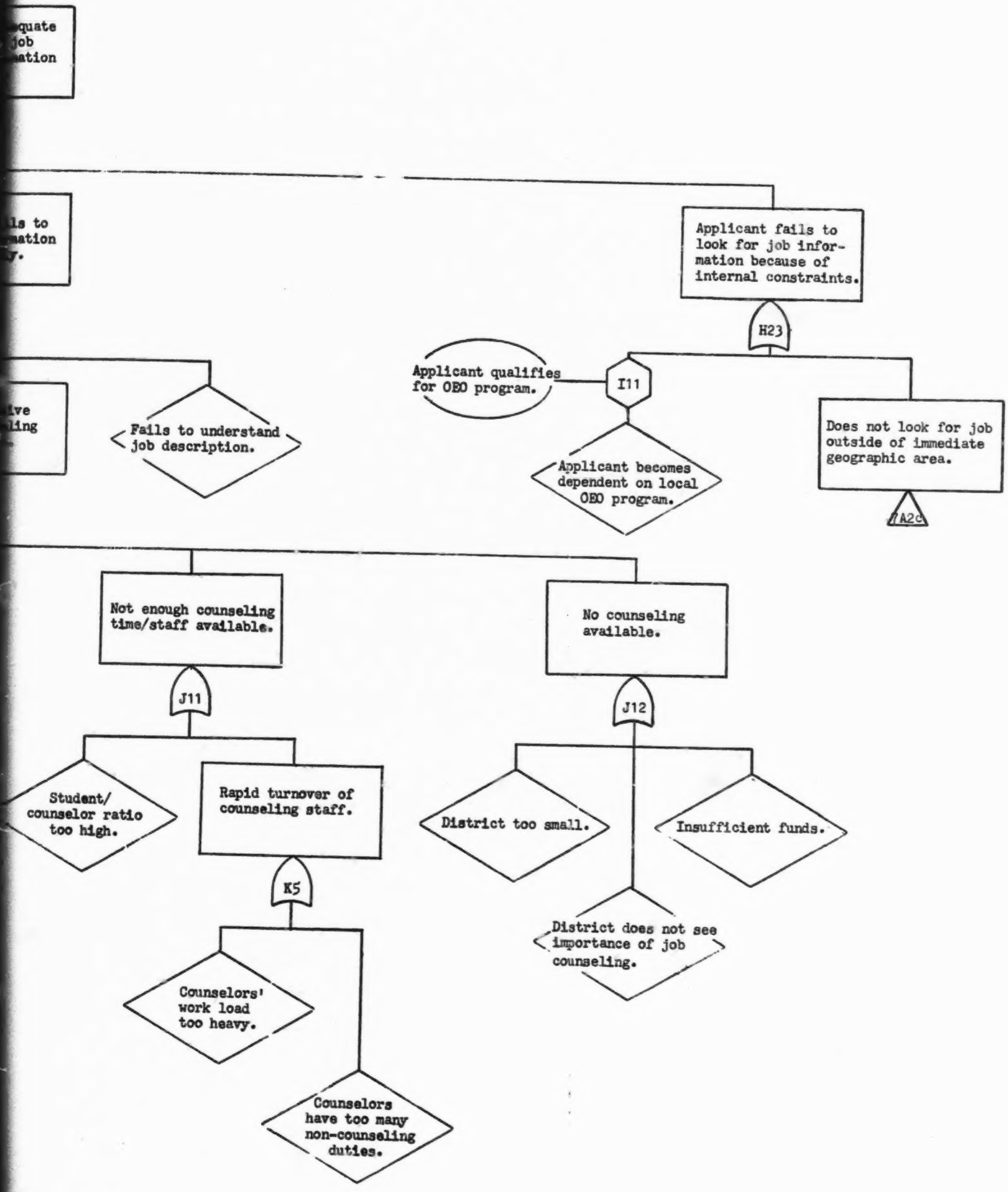

1 before 2
Failure to apply properly for job. 2
E43
Matrix Gate
any
roper
cation.
Fails to receive sufficient information on proper methods of job application.
Fails to put information into practice.
F36
F37
Failure of information on job application from school sources.
7A3
Failure of information from other sources.
Information received is not relevant to applicant.
Information is not reinforced through appropriate training.
G33
Information received too early for applicant.
Information received not appropriate for applicant.
Information received too late for applicant.
Failure of general recruitment methods.
H19
dvertize
ance of
Company policy results in inadequate recruitment methods.
Company size results in inadequate recruitment methods.
Age of company (too old, too new) results in inadequate recruitment methods.

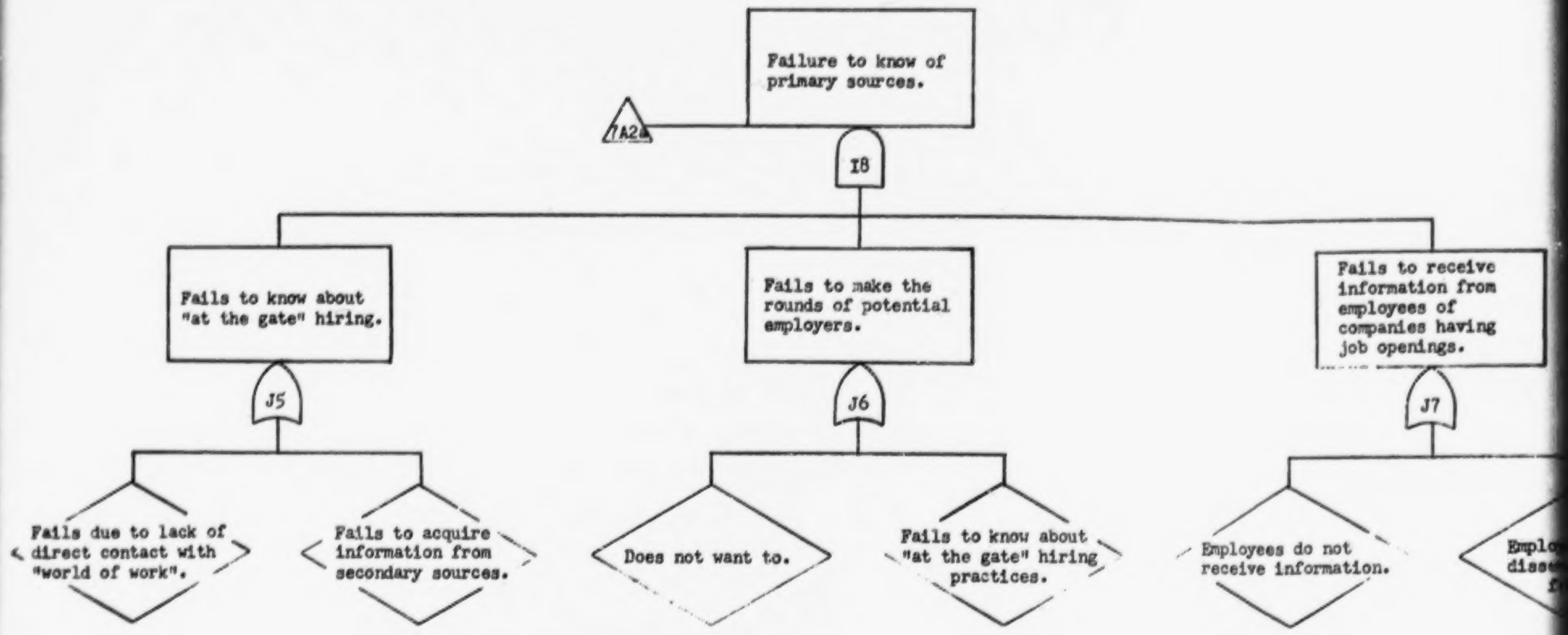
Types of failure:
1. Failure to keep appointment.
2. Failure to fill out forms properly.
3. Failure to be appropriately dressed.
4. Failure of appropriate demeanor and speech.
5. Failure to bring appropriate documents.
6. Failure to interact effectively during interview.

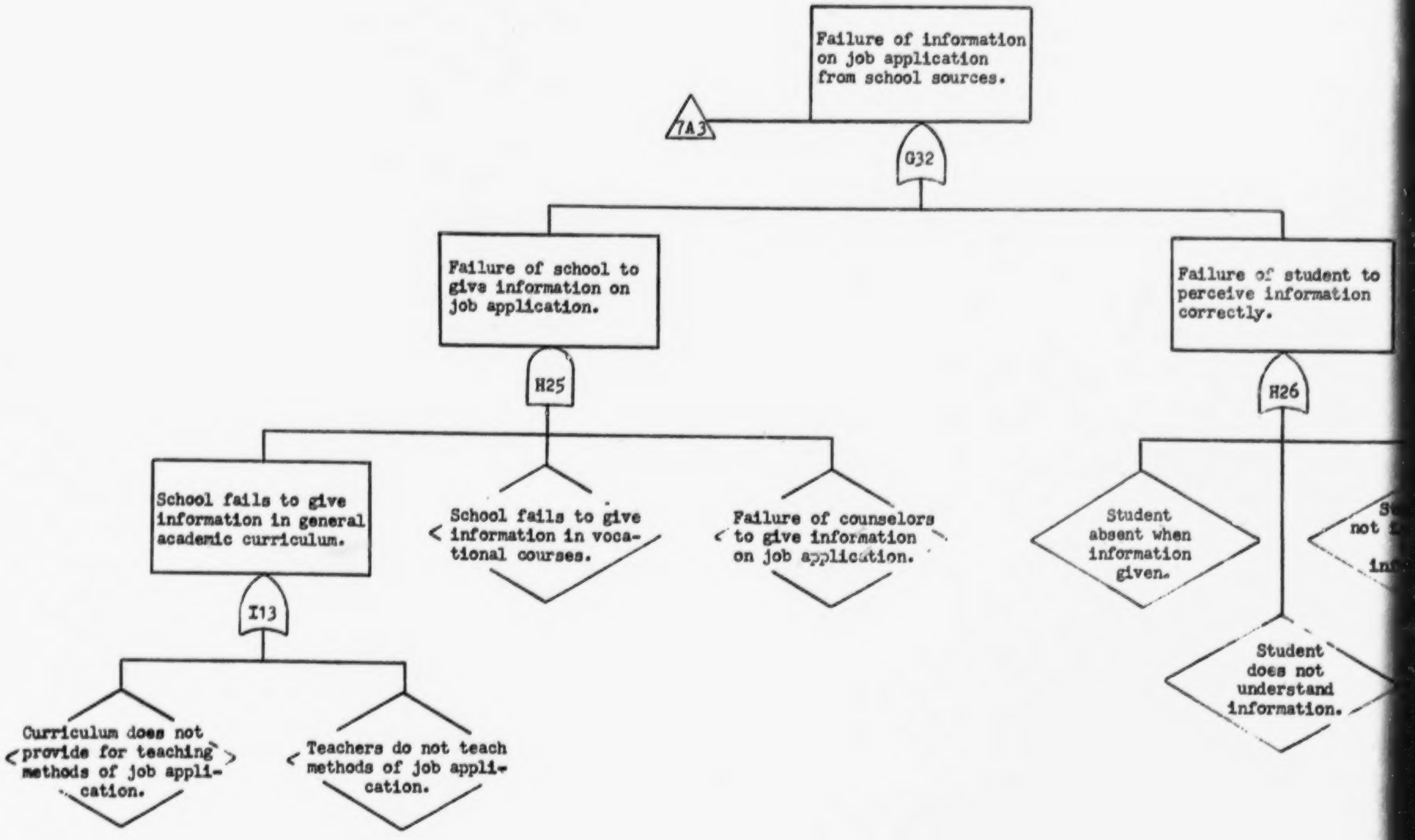

Failur
regard
inform
7A1
No data bank due to no job market surveys.
Data
openi
due
H20
Failure of labor market information.
Failure of job requirement information.
Faulty perception of input regarding job openings.
I5
Faulty perception due to distraction/preoccupation regarding input.
Faulty perception due to disinterest in input.
Input not i
readily usa
by teach
Failure of employer to utilize public schools.
7A4
J2
J3
Failure of industry to take the initiative in interfacing with schools.
Failure of schools to take the initiative in interfacing with industry.
Input comes too early for applicant.
Input discrepant with self-image of applicant (e.g. aspiration level).
Input comes too late for applicant.
K1
Failure of guidance and counseling services to interface with industry.
Failure of vocational education program to interface with industry.
L1
L2
Counselors have insufficient time.
Too few counselors.
No vocational education coordinators.
No time for interfacing.
Counselors fail to consider interface with industry as part of their job.
Coordinators fail to consider interface with industry as part of their job.

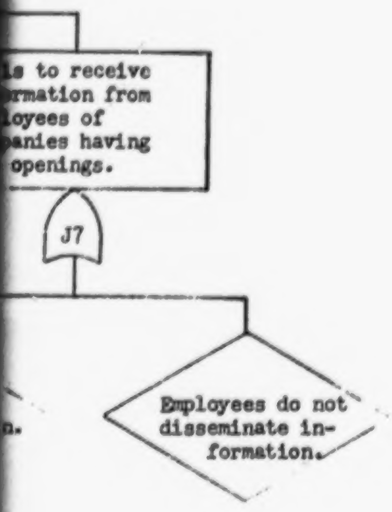

Failure of data bank regarding job opening information.
G30
Data bank of job openings inadequate due to faulty input.
Difficult to retrieve information from data bank.
H21
Input not in a readily usable form.
Faulty input due to failure in communication sources.
I6
Input not in a readily usable form by teachers.
Input not in a readily usable form by students.
I7
Matrix Gate
Types of faulty input:
1. Obsolete information.
2. Misleading information.
3. Insufficient number of occupations.
4. Insufficient number of firms.
5. Conflicting information.
6. Wrong timing.
Communication source failures.
J4
repant with
of appli-
aspiration
Faulty input from employers.
Faulty input from training agency (schools, etc.).
Faulty input from mass media.
Faulty input from parents, peers, etc.
Faulty input from placement agency.
K2
Public employment agencies.
Private employment agencies.

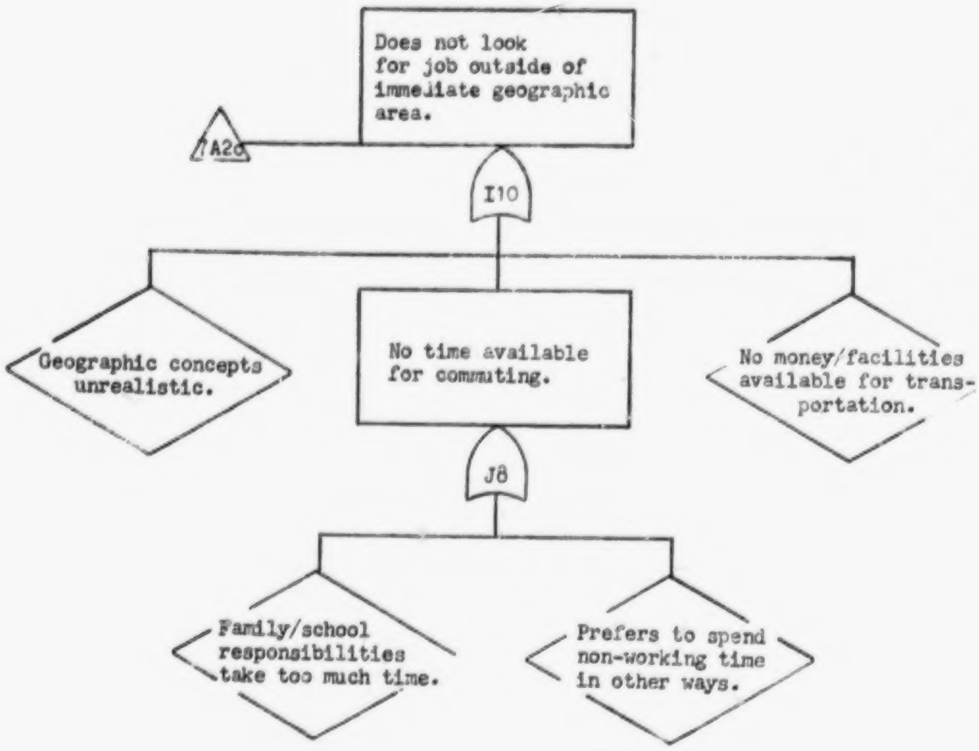

Failure of adequate retrieval of job opening information by applicant.
7A2
G31
Applicant fails to know sources of job information.
H22
Failure to know of primary sources.
7A2a
Failure to know of secondary sources.
7A2b
Applicant fails to use job information data correctly.
H24
Fails to apply job information to his own abilities.
Fails to receive proper counseling about the job.
Fails to
job descr
I12
Counselors have narrow view of their function.
J9
Inadequate training of counselors.
Counselors interested mainly in college preparation.
K3
Local community interested mainly in college preparation.
Administration interested mainly in college preparation.
Counselors have stereotyped ideas regarding the individual's potential.
J10
Failure of counselors to understand information.
Failure of counselors to search for relevant information.
Failure of counselors to use available information.
K4
Inappropriate image by counselors of "world of work."
Inadequately informed/trained counseling staff.
Not enough
time/staff
J11
Student/ counselor ratio too high.
Cou
wor
too

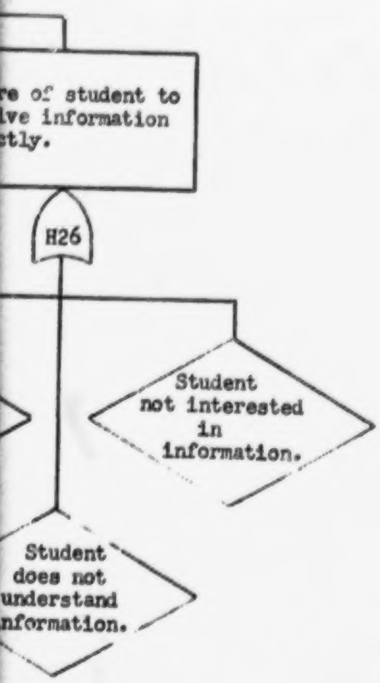

equate job ation
ls to mation y.
ive ling
Fails to understand job description.
Applicant fails to look for job information because of internal constraints.
H23
Applicant qualifies for OEO program.
I11
Applicant becomes dependent on local OEO program.
Does not look for job outside of immediate geographic area.
A2c
Not enough counseling time/staff available.
J11
Student/ counselor ratio too high.
Rapid turnover of counseling staff.
K5
Counselors' work load too heavy.
Counselors have too many non-counseling duties.
No counseling available.
J12
District too small.
Insufficient funds.
District does not see importance of job counseling.

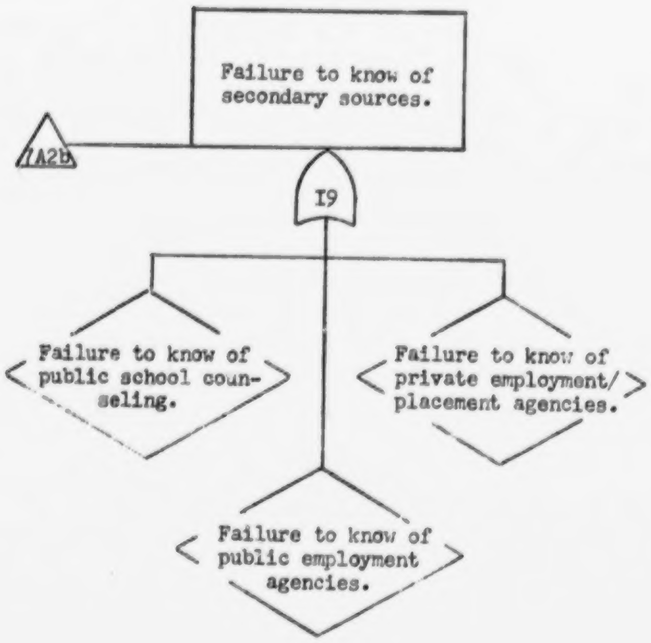

Failure to know of primary sources.
7A2
I8
Fails to know about "at the gate" hiring.
Fails to make the rounds of potential employers.
Fails to receive information from employees of companies having job openings.
J5
J6
J7
Fails due to lack of direct contact with "world of work".
Fails to acquire information from secondary sources.
Does not want to.
Fails to know about "at the gate" hiring practices.
Employees do not receive information.

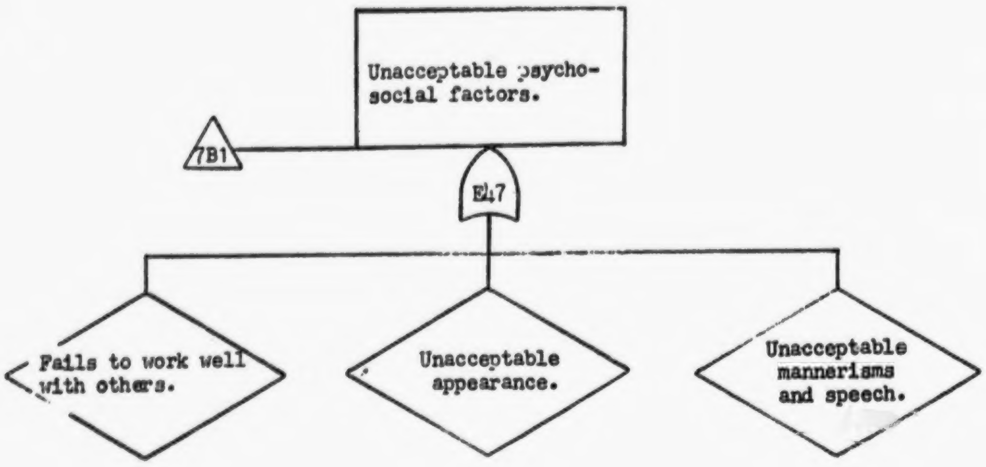

Failure of information on job application from school sources.
7A3
G32
Failure of school to give information on job application.
Failure of student to perceive information correctly.
H25
H26
School fails to give information in general academic curriculum.
School fails to give information in vocational courses.
Failure of counselors to give information on job application.
Student absent when information given.
Student does not understand information.
I13
Curriculum does not provide for teaching methods of job application.
Teachers do not teach methods of job application.

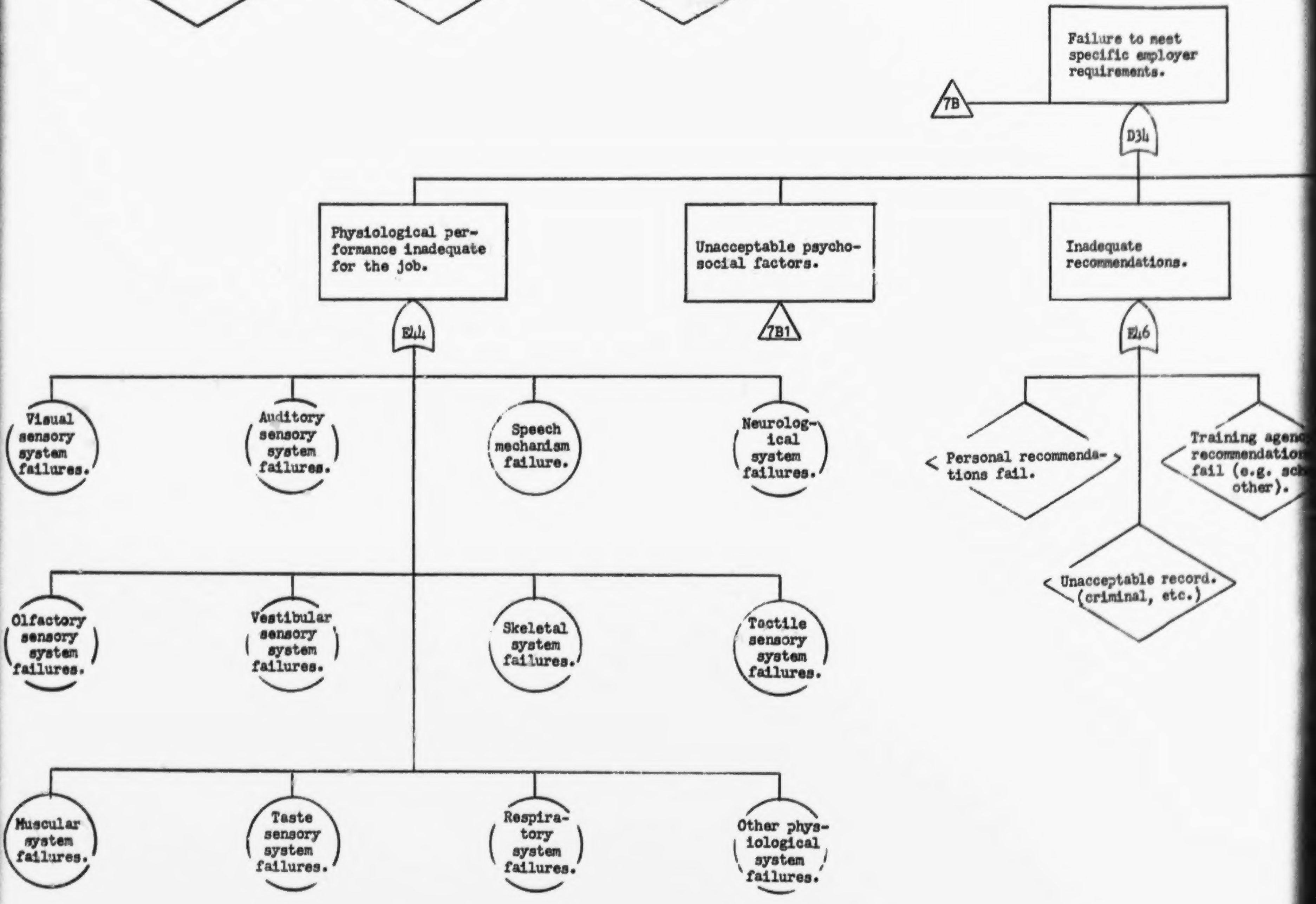

is to receive
ormation from
loyees of
panies having
openings.
J7
n.
Employees do not disseminate information.

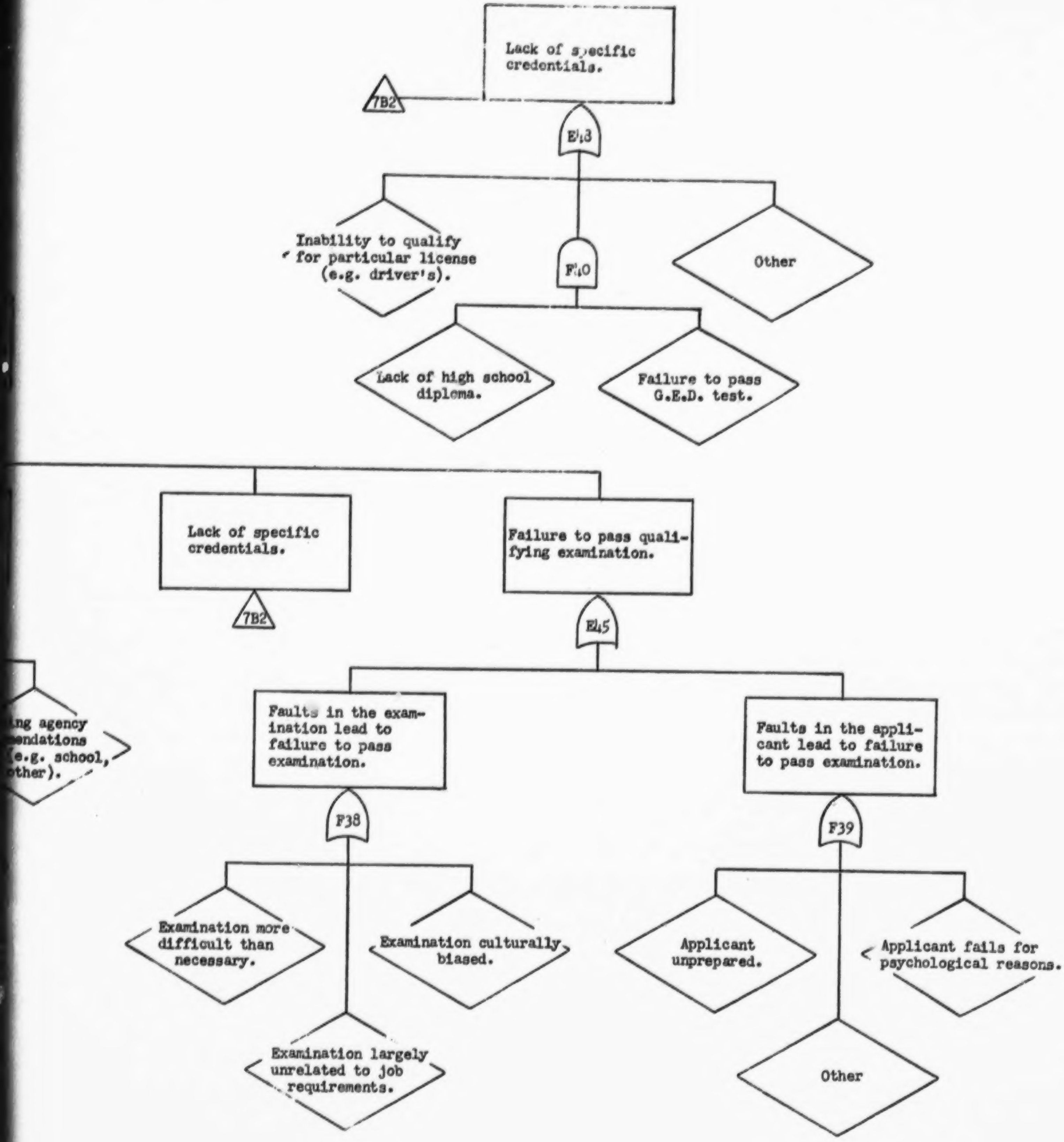

Does not look for job outside of immediate geographic area.
A2a
I10
Geographic concepts unrealistic.
No time available for commuting.
No money/facilities available for transportation.
J8
Family/school responsibilities take too much time.
Prefers to spend non-working time in other ways.

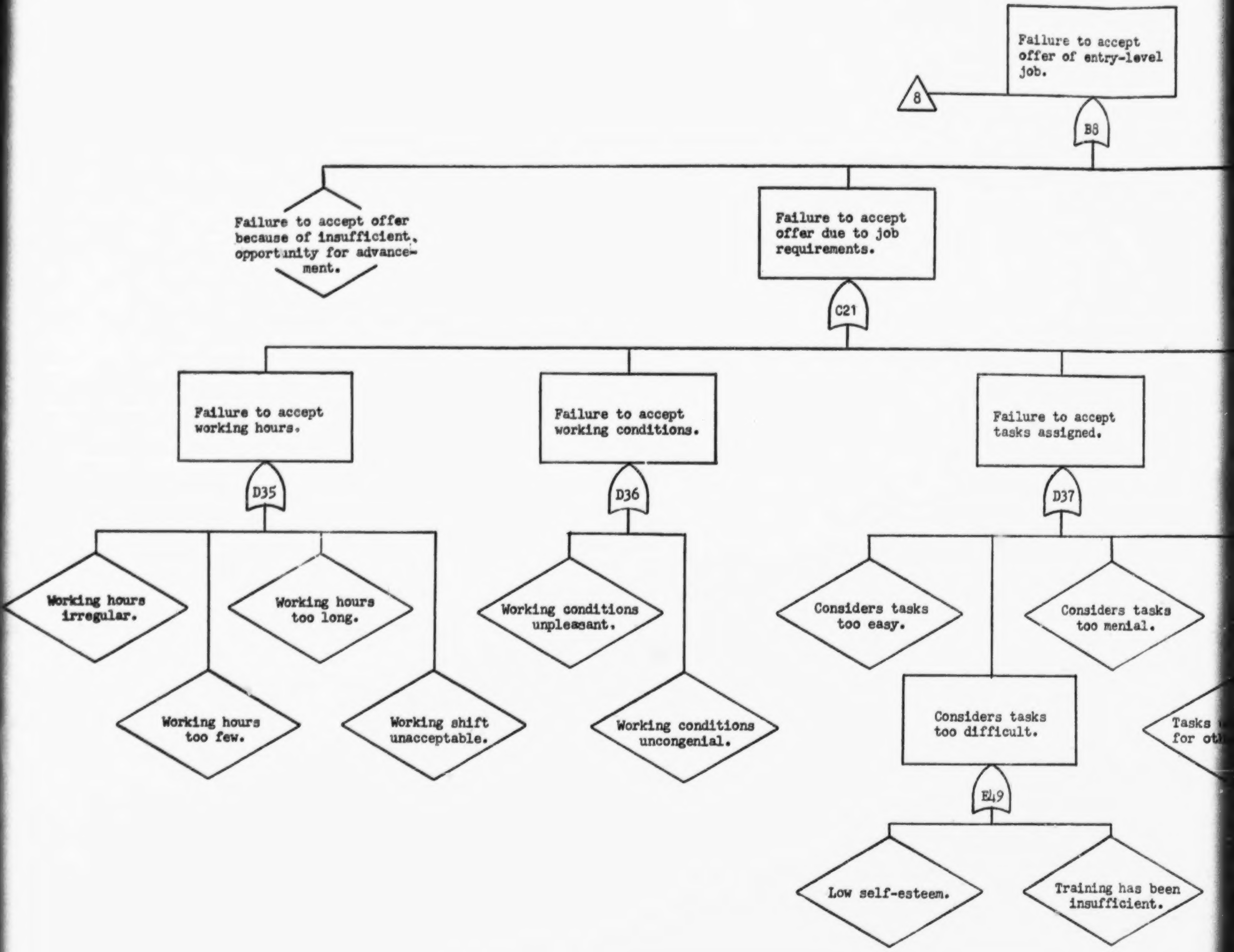

re of student to
ive information
tly.
H26
Student not interested in information.
Student does not understand information.

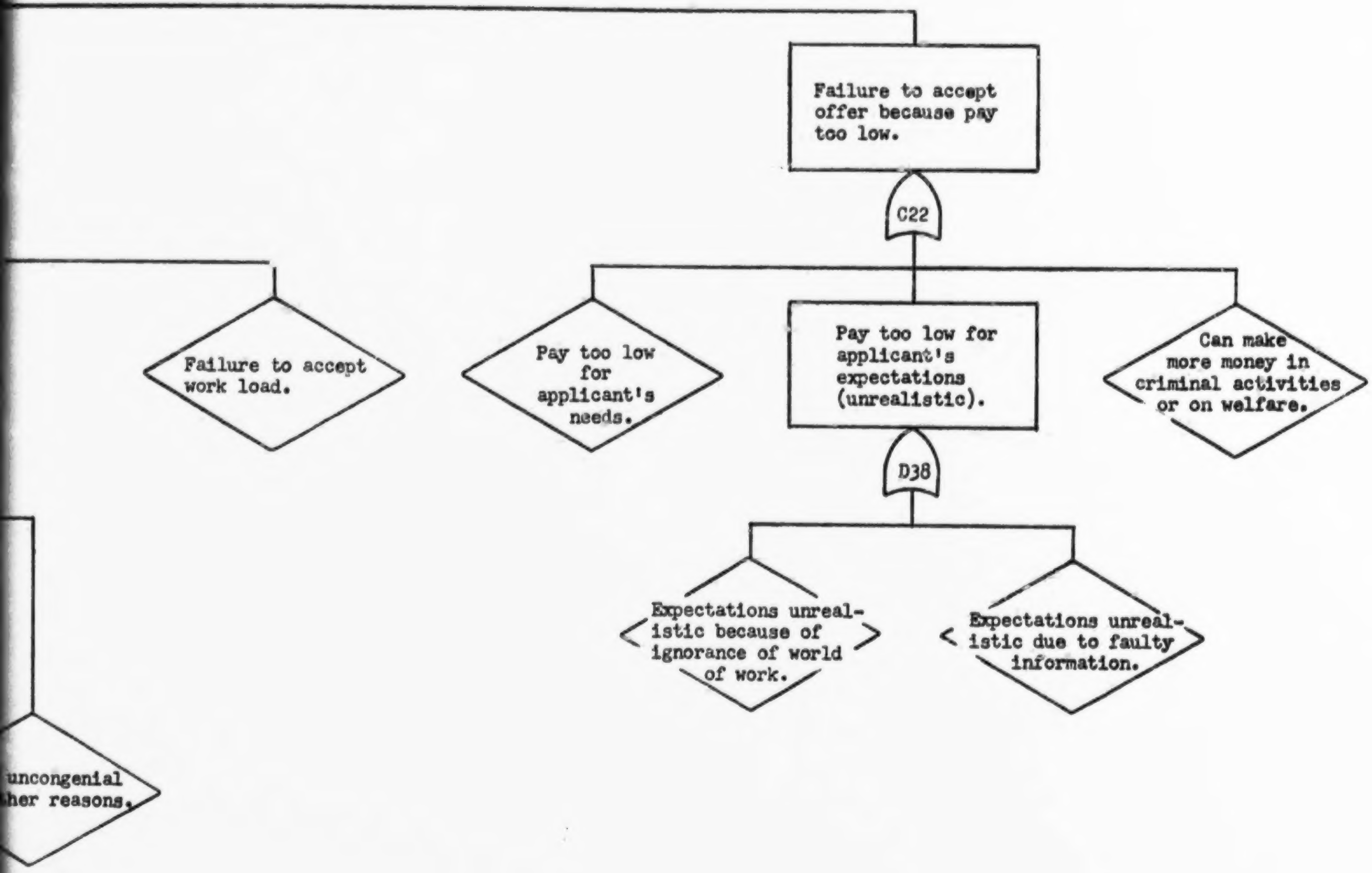

Failure to know of secondary sources.
A2b
I9
Failure to know of public school counseling.
Failure to know of private employment/placement agencies.
Failure to know of public employment agencies.


Unacceptable psycho-social factors.
7B1
E47
Fails to work well with others.
Unacceptable appearance.
Unacceptable mannerisms and speech.


Failure to meet specific employer requirements.
7B
D34
Physiological performance inadequate for the job.
Unacceptable psycho-social factors.
7B1
Inadequate recommendations.
E44
E46
Visual sensory system failures.
Auditory sensory system failures.
Speech mechanism failure.
Neurological system failures.
Personal recommendations fail.
Training agency recommendations fail (e.g. sch other).
Unacceptable record. (criminal, etc.)
Olfactory sensory system failures.
Vestibular sensory system failures.
Skeletal system failures.
Tactile sensory system failures.
Muscular system failures.
Taste sensory system failures.
Respiratory system failures.
Other physiological system failures.


Lack of specific credentials.
7B2
E43
Inability to qualify for particular license (e.g. driver's).
F40
Other
Lack of high school diploma.
Failure to pass G.E.D. test.
Lack of specific credentials.
7B2
Failure to pass qualifying examination.
E45
ing agency
mendations
(e.g. school,
other).
Faults in the examination lead to failure to pass examination.
Faults in the applicant lead to failure to pass examination.
F38
F39
Examination more difficult than necessary.
Examination culturally biased.
Examination largely unrelated to job requirements.
Applicant unprepared.
Applicant fails for psychological reasons.
Other


Failure to accept offer of entry-level job.
8
B8
Failure to accept offer because of insufficient opportunity for advancement.
Failure to accept offer due to job requirements.
C21
Failure to accept working hours.
D35
Failure to accept working conditions.
D36
Failure to accept tasks assigned.
D37
Working hours irregular.
Working hours too long.
Working hours too few.
Working shift unacceptable.
Working conditions unpleasant.
Working conditions uncongenial.
Considers tasks too easy.
Considers tasks too menial.
Considers tasks too difficult.
Tasks
for oth
E49
Low self-esteem.
Training has been insufficient.


Failure to accept offer because pay too low.
C22
Failure to accept work load.
Pay too low for applicant's needs.
Pay too low for applicant's expectations (unrealistic).
Can make more money in criminal activities or on welfare.
D38
Expectations unrealistic because of ignorance of world of work.
Expectations unrealistic due to faulty information.
uncongenial
her reasons.